— Enclosure 01 —

RADIOLOGICAL SURVEY
U.S. ARMY RESERVE PROPERTY
WELDON SPRING SITE
ST. CHARLES COUNTY, MISSOURI

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Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites - Remedial Action Program

FINAL REPORT

January 1986

This report is based on work performed under contract number DE-AC05-76OR00033 with the U.S. Department of Energy.

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DOCUMENT NUMBER: I-300-302-1.01

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INTRODUCTION

From 1957 to 1966 the Weldon Spring Chemical Plant in St. Charles County, Missouri, was used to convert uranium ore concentrates and recycled uranium scrap to uranium tetrafluoride, uranium trioxide, and metallic uranium. Smaller quantities of thorium oxide were also processed at these facilities. The plant was operated by Mallinckrodt Chemical Works - Uranium Division, under contract with the Atomic Energy Commission (AEC). Residues and contaminated wastes from these operations were placed in four onsite raffinate pits. During the same period, and for several years following the termination of uranium and thorium processing operations, the AEC also disposed of residues, contaminated scrap, and building rubble in an abandoned rock quarry, approximately 5 km southwest of the chemical plant site. Since termination of AEC activities in 1969, the chemical plant and the quarry have remained essentially unused and in caretaker status.

As successor to the AEC, the Department of Energy (DOE) is responsible for the management and ultimate disposal of the radioactive wastes from previous operations of the Weldon Spring Chemical Plant. Although wastes are primarily limited to the pits, quarry, and the chemical plant, aerial and surface monitoring have identified low-level contamination on portions of the surrounding properties. Water monitoring has also indicated elevated radionuclide levels in several of the springs and lakes on the adjacent properties. At the request of the Department of Energy's Office of Nuclear Energy, the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) conducted a radiological survey of the United States Army Reserve Property, adjacent to the former Weldon Spring Chemical Plant, to determine the extent and levels of offsite contamination resulting from previous AEC operations and current onsite waste storage.

SITE HISTORY

In 1941, the Department of the Army acquired 6,974 hectares, surrounding what is now the Weldon Spring Chemical Plant, as the site for an explosives production facility known as the Weldon Spring Ordnance Works. Following shut down of Ordnance Works in 1944, land which was declared surplus to army needs was transferred to the Missouri State Conservation Commission for wildlife conservation; the University of Missouri for agricultural purposes; and the St. Charles County Consolidated School District. The remaining land (835 ha) was placed under the control of the Department of the Army. In 1959, 752 ha was designated as a U.S. Army Reserve Training area. Of that amount, 6 ha was transferred to the AEC in 1964 for construction of raffinate pit #4. Currently, the U.S. Army Reserve area is comprised of the remaining 746 ha. There is no history of storage, use or disposal of radioactive material on the Army Reserve Property.

SITE DESCRIPTION

The Weldon Spring site is located on State Highway 94, approximately 22 km southwest of St. Charles, Missouri (Figure 1). The nearest community is Weldon Spring at the intersection of Highway 94 with U.S. Highways 40 and 61. Vicinity properties are indicated in Figure 2. The U.S. Army Reserve Property is a fenced area occupying approximately 746 hectares. The land is relatively level. Portions of the property are cleared and easily accessible while other sections are wooded or overgrown with heavy brush. An extensive system of drainage ditches exists on the property, primarily for surface runoff. One main easement, herein called the Southeast Drainage Easement, runs south from the Weldon Spring Chemical Plant to the Missouri River. This easement crosses the southeast corner of the Army Reserve Property for approximately 300 m. The site contains numerous paved and unpaved roads, several inactive railroad tracks, a few small lakes or ponds and many small buildings. Remnants of other railroad tracks and buildings, previously associated with ordnance manufacturing operations, remain on the property.

SURVEY PROCEDURES

The survey of the Army Reserve Property, Weldon Spring Site was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) during March-July 1985. The survey was performed in accordance with a survey plan dated December 21, 1984 and approved by the Department of Energy's Office of Nuclear Energy. The methods and procedures utilized in that survey are presented in this section.

Aerial photographs and drawings of the Weldon Spring Site, including the U.S. Army Reserve Property, dating from 1957 to the present were reviewed to aid in determining the best radiological survey approach and most probable sites of contamination.

Field Procedures

1. Walkover surface scans were conducted at 1-2 m intervals over interior and perimeter roads, trails, railroads and major surface drainage pathways. Portable gamma NaI(Tl) scintillation survey meters were used for these scans. Areas with elevated radiation levels were noted for further definitive surveys.

2. Gamma measurements were made at the surface and at 1 m above the surface at 100 m intervals along major roadways, railroads and drainage ditches. These measurements were made either to the left (L), right (R) or in the center (C) of the traverse unless otherwise indicated. The measurements were made using portable NaI(Tl) scintillation meters and results were converted to exposure rates in microroentgens per hour (μR/h) by comparison with a calibrated pressurized ionization chamber.

   Direct radiation measurements were also made at locations of elevated surface levels as identified by the walkover surface scans.

3. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at 100 m intervals along major roadways, railroads and

drainage ditches. Samples were collected 1 m to the left (L), right (R) or in the center (C) of the traverse unless otherwise indicated.

4. Grid systems were established in two areas where more extensive surface contamination was identified by walkover scans.

Walkover surface scans were conducted at 1-2 m intervals over the entire gridded area using gamma scintillation detectors. Locations of elevated contact radiation levels were noted for further sampling.

Gamma measurements were made at the surface and at 1 m above the surface at each grid intersection and at elevated locations identified by the walkover scan.

Dose rate measurements were measured 1 cm above the surface at each gridline intersection using thin-window (<7 mg/cm^2) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate the contribution of nonpenetrating beta and low-energy gamma radiations. Meter readings were converted to dose rates in microrads per hour (μrad/h).

Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each accessible grid intersection and at selected locations identified by the walkover scan.

5. Nineteen boreholes were drilled on the Army Reserve Property at locations shown on Figure 3. Boreholes were drilled by Continental Drilling using a truck-mounted hollow stem auger. Locations of the boreholes were selected based on site accessibility and results of surface measurements and analysis of surface soil samples. Locations were selected to provide representative coverage of the Army Reserve Property and further examine areas of contamination.

Radiation profiles of the boreholes were determined by measuring gamma radiation at 30 cm intervals from the surface to the bottom of the borehole using a collimated NaI(Tl) gamma scintillation probe and portable scaler.

Samples of subsurface soil were obtained at various depths using a split-spoon sampler.

Ground water samples were obtained from five of the boreholes.

Soil samples were collected from shallow boreholes, ranging in depth from the soil surface to 100 cm, at selected locations of elevated surface radiation levels identified by the walkover surface scan.

6. Samples of surface water were collected from creeks, ponds, drainage ditches, and easements (Figure 4).

7. Sediment samples were obtained at locations of surface water sampling and also at 100 m intervals along major surface drainage ditches. Additional sediment samples were collected in areas of contamination identified in the walkover scans.

8. Buildings which were intact and accessible were scanned using NaI gamma scintillation meters. Direct alpha and beta-gamma surface measurements were made on floors, walls, ceilings, and equipment. Smear samples were obtained for measurement of transferable alpha and beta contamination. Buildings which were no longer intact and consisted mainly of rubble and concrete were scanned using NaI(Tl) gamma scintillation meters. Figure 5 shows the location of buildings on the Army Reserve Property.

9. Six soil samples and five water and sediment samples were collected from the Weldon Spring area (but not on the Weldon Spring Chemical Plant or associated vicinity properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 6.

10. Civil surveys were performed by a local surveying agency to identify areas of contamination relative to the ordnance grid coordinate

system. (Because of the distances of some areas from state grid benchmarks, it was not possible to tie locations to the state grid coordinate system.) Permanent markers were installed at each of the contaminated areas.

Sample Analysis Procedures/Data Analysis Procedures

Soil and sediment samples were analyzed by gamma spectrometry. Radionuclides of interest included U-238, Th-232, and Ra-226, however, the spectra were also reviewed for other gamma emitters. Water samples were analyzed for gross alpha and gross beta concentrations. In addition, water samples which exceeded 15 pCi/l gross alpha, were analyzed for Ra-226, Ra-228, and isotopic uranium concentrations. Two samples were also analyzed for isotopic thorium. Smear samples were analyzed for transferable gross alpha and beta contamination. Additional information concerning equipment and procedures is contained in Appendices A and B.

Results of this survey were compared to the DOE guidelines for residual radioactivity at formerly utilized and surplus facilities sites. (Refer to Appendix C)

RESULTS

The results of this survey are presented in two sections. Part A provides general survey findings, identifying locations of contamination. Further characterization of these contaminated areas is discussed in Part B.

A. General Survey Results

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil determined for the vicinity of the Weldon Spring vicinity properties are presented in Table 1A. Exposure rates ranged from 5 to 8 μR/h. Concentration of radionuclides in soil were: Ra-226, 0.55 to 0.92 pCi/g (picocuries per gram); U-238, <0.68 to 1.62 pCi/g; and Th-232, 0.95 to 1.48 pCi/g. These

concentrations are typical of the radionuclide levels normally encountered in surface soils.

Baseline radionuclide concentrations determined in sediment are presented in Table 1B. Radium-226 concentrations ranged from 0.35 to 0.92 pCi/g; U-238 concentrations ranged from <0.66 to 1.4 pCi/g and Th-232 concentrations ranged from 0.24 to 1.02 pCi/g. These concentrations are typical of radionuclides normally encountered in sediment.

Radioactivity levels in baseline water samples are presented in Table 1C. Gross alpha concentrations ranged from 0.48 to 4.09 pCi/l (picocuries per liter). Gross beta concentrations ranged from 3.50 to 7.39 pCi/l. These are typical concentrations normally occurring in surface water.

Army Property Railroad System

Direct Measurements

Direct radiation levels, measured at 100 m intervals along the entire railway system within the Army property (Figure 7), are presented in Tables 2 and 3. The gamma exposure rates measured at 1 m above the surface ranged from 6 to 13 μR/h. Surface exposure rates ranged from 6 to 9 μR/h.

The walkover survey identified two areas of generally elevated surface radiation levels containing numerous "hot spots" (designated as Locations #1 and #2), and one smaller area with a few isolated "hot spots", which has been designated as Location #3.

Radionuclide Concentrations in Surface Soil

Radionuclide concentrations measured at 100 m intervals along the Army Property Railways are presented in Tables 4 and 5. All concentrations measured are within the normal range of baseline samples, with the exception of the concentrations measured along Railroad #2' (refer to Table 5) which is adjacent to an area which has been identified as contaminated (Location #1). Uranium-238 concentrations measured at 50 m intervals along Railroad #2' ranged

from 0.98 to 143 pCi/g. Radium-226 and Th-232 concentrations are within the normal baseline ranges.

Major Army Property Roads

Direct Measurements

Direct radiation levels, measured at 100 m intervals along the major roads (Figures 8, 9 and 10), are presented in Tables 6-12. The gamma exposure rates at 1 m above the surface ranged from 5 to 9 μR/h and surface contact gamma exposure rates were from 5 to 8 μR/h.

The walkover survey of the major roads identified one isolated "hot spot", one meter to the north of Road #1, 1154 m from the property entrance gate. This spot has been designated as Location #7 and is shown on Figure 11.

Radionuclide Concentration in Surface Soil

Concentrations of radionuclides measured in surface soil collected at 100 m intervals are presented in Tables 13-19. Levels of Ra-226, U-238 and Th-232 were below the minimum detectable activity or within the range of the baseline samples.

Secondary Army Property Roads

Walkover surveys of approximately 75% of the secondary roadways did not indicate any areas of elevated surface radiation; further measurements and sampling were therefore not performed along these roadways.

Major Surface Drainage Ditches

Direct Measurements

Direct radiation levels measured at 100 m intervals along the major surface drainage ditches (#4, #4A, ditch from Location #1 - Figure 4) are presented in Table 20. Gamma exposure rates measured at 1 m above the surface ranged from 7 to 11 μR/h and surface measurements ranged from 7 to 14 μR/h.

Gamma exposure rates measured along a short section of drainage ditch paralleling the underground section of the Southeast Drainage Easement (Figure 17) ranged from 5 to 8 μR/h at the surface. Because these were background levels and no elevated radiation levels were identified, additional measurements and sampling were not performed along this ditch.

The Southeast Drainage Easement is designated as Location #4 and is discussed in Results Section B.

Two areas of elevated surface radiation levels were identified by the walkover scan. All of the ditch running from the fenceline near the raffinate pit to ditch #4 has been designated as Location #5. The first 200 m of ditch #4, near the Army property fenceline has been designated as Location #6.

Radionuclide Concentrations in Sediment

Concentrations of radionuclides measured at 100 m intervals along the major surface drainage easements are presented in Table 21. Uranium-238 concentrations ranged from 0.46 to 59.2 pCi/g. The latter value was from a sample taken from ditch #4 at the Army property fenceline (Location #6). All other Uranium-238 values were <12.5 pCi/g. Radium-226 and Th-232 concentrations ranged from 0.53 to 1.57 pCi/g and 0.62 to 2.23 pCi/g, respectively.

Radionuclide Concentrations in Water

Radionuclide concentrations measured in water from surface drainage ditches were within the normal baseline values (Table 22).

Schote Creek

Direct Measurements

Direct radiation levels measured at 100 m intervals along Schote Creek are presented in Table 23. Gamma exposure rates measured at the surface and 1 m above the surface did not exceed 8 μR/h.

Radionuclide Concentrations in Sediment

Radionuclide concentrations measured in sediment collected at 100 m intervals along Schote Creek are presented in Table 23. All concentrations measured were within the range of baseline concentrations.

Army Property Ponds

Radionuclide Concentrations in Surface Water

Radionuclide concentrations measured in two ponds located on the Army Reserve property (Figure 4) are presented in Table 22. Gross alpha and beta concentrations are within the range of baseline concentrations.

Radionuclide Concentrations in Sediment

Sediment samples obtained at locations of surface water sampling contain concentrations within the range normally encountered in baseline samples (Table 25).

Borehole Gamma-Logging Measurements

The locations of boreholes drilled on the Army Property are shown on Figure 3. Borehole gamma-logging did not identify any elevated subsurface radiation levels. Logging data were not used to quantify radionuclide concentrations in the subsurface soil due to the absence of significant positive findings and the varying ratios of different gamma-emitting radionuclides in soils at this site.

Radionuclide Concentrations in Subsurface Soil from Boreholes

Radionuclide concentrations measured in subsurface soil from boreholes are presented in Table 26. None of the 19 boreholes contained subsurface radionuclide concentrations significantly different from baseline soil concentrations.

Radionuclide Concentrations in Subsurface Water from Boreholes

Gross alpha and beta concentrations in subsurface water samples collected from five boreholes are presented in Table 27. Gross alpha concentrations ranged from 0.60 to 9.10 pCi/l, which is within the range normally encountered in nature.

Building Surveys

The results of the building surveys for buildings 1-3 and 14-21 are summarized in Table 28. No areas of elevated direct radiation or surface contamination were noted. Further building measurements were therefore not necessary.

Walkover surveys of the rubble remaining from buildings 4-13 did not identify any areas of elevated surface measurements. Gamma exposure rates ranged from 5 μR/h to 10 μR/h.

B. Results at Identified Locations of Contamination

Location #1

Location #1 is adjacent to the Bechtel/DOE access road (Figure 7). A 10 m grid system was established in the southeast corner of Location #1 covering from 0 North to 50 North and 0 West to 50 West (Figure 12). Adjacent areas within Location #1 were sampled using either a 20 m or a 40 m grid interval. The larger grid intervals were used as surface radiation levels approached background levels.

Direct Measurements

Direct radiation levels measured at grid intersections are presented in Table 29. The gamma exposure rates measured at 10 m grid intervals 1 m above the surface ranged from 7 to 52 μR/h. Surface contact gamma exposure rates and beta-gamma dose rates ranged from 6 to 56 μR/h, and 6 to 1280 μrad/h, respectively. Within the 20 m and 40 m grids, gamma exposure rates 1 m above

the surface ranged from 4 to 9 μR/h. At surface contact the exposure rates ranged from 4 to 11 μR/h and beta-gamma dose rates ranged from 4 to 44 μrad/h. Measurements performed with the detector shielded averaged approximately 40% less than those with the unshielded detector. This indicates that a small portion of the surface dose rate is due to nonpenetrating beta or low energy photon radiations. Exposure rates and dose rates were highest within the 10 m grid area and dropped to background levels within the 40 m grid section.

The walkover survey identified numerous locations of elevated surface radiation levels. These locations are indicated in Figure 13 and associated direct radiation levels are presented in Table 30. Contact gamma exposure rates ranged from 15 to 660 μR/h. Gamma exposure rates at 1 m above the surface and contact beta-gamma dose rates ranged from 7 to 59 μR/h and 610 to 60460 μrad/h, respectively.

Radionuclide Concentration in Surface Soil from Grid Intersections

Table 31 lists the concentrations of radionuclides measured in surface soil from 10 m, 20 m and 40 m grid intervals. Samples obtained from the 10 m grid area contained Ra-226 concentrations ranging from 0.42 to 18.1 pCi/g. The concentration of U-238 ranged from 0.60 to 1100 pCi/g and Th-232 concentrations ranged from 0.13 to 4.82 pCi/g. Radionuclide concentrations collected from the 20 m and 40 m grid sections are within the range encountered in baseline soil samples.

Radionuclide Concentration in Soil from Boreholes

Radionuclide concentrations measured in soil samples from randomly spaced shallow boreholes are presented in Table 32. Radium-226 concentrations ranged from 0.89 to 1.22 pCi/g. Concentrations of U-238 and Th-232 ranged from 1.01 to 4.35 pCi/g and 0.79 to 1.42 pCi/g, respectively.

Radionuclide concentrations in borehole samples from areas identified as having surface contamination are presented in Table 33. Uranium-238 concentrations ranged from 2.76 to 29,530 pCi/g. Radium-226 concentrations ranged between 0.70 and 40.1 pCi/g. Concentrations of Th-232 ranged from <0.46

to 450 pCi/g. Uranium-238 contamination was noted to at least 1 m below the soil surface.

At many locations of elevated contact radiation levels, pieces of metal, debris, and slag were encountered while sampling, preventing deeper samples from the same area. A 1.7 kg slag sample obtained at 8N, 14W had a total U-238 activity of 1.4 mCi (millicuries).

Radionuclide Concentration in Surface Water

Two samples of surface water were collected from the drainage ditch within Location #1 (Figure 12) and the radionuclide concentrations are presented in Table 34. Gross alpha and beta measurements in the sample collected at 18N, 50W were 3070 pCi/l and 4220 pCi/l, respectively. Uranium-238 and U-234 concentrations were 1699 pCi/l and 1643 pCi/l; Ra-226 and Ra-228 were <0.08 pCi/l and 0.2 pCi/l, respectively. The sample from 38N, 90W had gross alpha levels of 0.90 pCi/l and gross beta concentrations of 6.43 pCi/l.

Radionuclide Concentration in Drainage Ditch Sediments

Radionuclide concentrations in sediment samples, collected from locations along the drainage ditches within Location #1, are presented in Table 35. Radium-226 concentrations ranged from 0.60 to 1.27 pCi/g. Uranium-238 and Th-232 ranged from 1.09 to 781 pCi/g and 0.48 to 11.40 pCi/g.

Location #2

A 10 m grid system was established along an 80 m x 20 m section of Railroad #2 (Figures 7 and 14), and is designated as Location #2.

Direct Measurements

Direct radiation levels measured at the grid points are presented in Table 36. Contact gamma exposure rates ranged from 6 to 13 μR/h. Gamma exposure rates at 1 m above the surface and beta-gamma dose rates ranged from 6 to 14 μR/h and 7 to 120 μrad/h, respectively.

Direct radiation levels measured at locations identified in the walkover scan are presented in Table 37; their positions in the grid are shown in Figure 15. Gamma exposures rates at 1 m above the surface ranged from 8 to 21 μR/h. Contact gamma exposure rates and beta-gamma dose rates ranged from 17 to 150 μR/h and 92 to 4950 μrad/h, respectively.

Radionuclide Concentration in Surface Soil

The concentrations of radionuclides measured in surface soil collected at grid point intersections are listed in Table 38. The concentration of U-238 ranged from <0.97 to 57 pCi/g. Thorium-232 concentrations ranged from 0.49 to 1.91 pCi/g; Ra-226 concentrations ranged from 0.64 to 1.84 pCi/g.

Radionuclide Concentration in Soil from Boreholes

Location 2

Radionuclide concentrations measured in soil samples from shallow boreholes are presented in Table 39. Uranium-238 concentrations ranged from 160 to 1350 pCi/g. Concentrations of Ra-226 and Th-232 ranged from 0.99 to 5.00 pCi/g and 0.88 to 2.28 pCi/g, respectively.

At some locations of elevated contact radiation levels, pieces of metal and debris were encountered within the top 15 cm of soil. In many cases, the contact radiation levels decreased to background levels once the objects were removed. Contamination in most locations extends to at least 30 cm below the soil surface.

Concentrations of radionuclides in soil samples collected from two isolated locations identified in the walkover scan 23 m west of the gridded area are presented in Table 39. Uranium-238 and Ra-226 concentrations ranged from 10.1 to 390 pCi/g and 2.78 to 36.2 pCi/g, respectively.

Location #3

Location #3 is a wooden loading dock situated adjacent to Railroad #2, approximately 450 m from Location #2 (Figure 15). The structure rises approximately 4.5 m above railroad #2. Railroad #2B ends at the top of the loading dock.

Direct Measurements

Gamma exposure rates of 33 μR/h were measured in the area directly beneath the corners of the loading dock and 22 μR/h was measured on the southeast corner on the top of the loading dock.

Radionuclide Concentration in Surface and Subsurface Soil

Location 3

Radionuclide concentrations measured in samples obtained from the top of the loading dock and directly beneath the corners of the loading dock are presented in Table 40. Concentration of U-238 ranged from 436 to 2640 pCi/g and Ra-226 concentrations ranged from 0.82 to 4.46 pCi/g. Thorium-232 concentrations were below the minimum detectable activity.

The concentration of U-238 in the sample collected at the southeast corner of the top of the loading dock was 1042 pCi/g and the Ra-226 concentration was 4.46 pCi/g. The range of Ra-226 concentration in soil from the shallow borehole dug at the north east corner, lower level, of the loading dock was 0.82 to 3.14 pCi/g. The U-238 concentration ranged from 2640 pCi/g in the top 15 cm of soil to 477 pCi/g in the sample obtained from 45-60 cm below the soil surface.

Location #4

Location #4 is a short section of the main drainage easement running from the Imhoff Tanks within the Weldon Spring Chemical Plant to the Missouri River (Figure 17). It crosses the southeast corner of the Army property and is referred to as the Southeast Drainage Easement. The runoff flows through a 20 cm diameter underground cement pipe and surfaces approximately 200 m southeast of the chemical plant property fenceline. This drainage ditch continues above ground for approximately 305 m to the perimeter fence between the Army Property and Weldon Spring Wildlife Area.

Direct Measurements

Direct radiation levels, measured at soil sampling locations and at locations identified in the walkover scan along the length of the drainage

easement crossing Army Reserve Property are presented in Table 41. Gamma exposure rates at 1 m above the surface ranged from 8 to 29 μR/h and exposure rates at the surface ranged from 7 to 120 μR/h.

Radionuclide Concentration in Soil

Radionuclide concentrations measured in surface soil at 100 m intervals along the easement are presented in Table 42. Concentrations of U-238 ranged from 1.26 pCi/g to 42.0 pCi/g. Radium-226 and Th-232 concentrations were from 0.76 to 8.36 pCi/g and 0.43 to 2.69 pCi/g, respectively.

Radionuclide Concentrations in Sediment

Concentrations measured in sediment samples collected at 100 m intervals are presented in Table 42. Uranium-238 concentration ranged from <1.56 to 39.7 pCi/g and Ra-226 concentration ranged from 4.34 to 6.57 pCi/g. The concentration of Th-232 ranged from 1.41 to 2.14 pCi/g.

Radionuclide Concentrations in Soil from Shallow Boreholes

Concentrations of radionuclides measured in soil samples from shallow boreholes are presented in Table 43. Five of the six boreholes contained elevated U-238 concentrations ranging up to 1010 pCi/g. Radium-226 concentrations ranged from 2.04 to 210 pCi/g and Th-232 levels ranged from 0.88 to 69.1 pCi/g. Radionuclide concentrations measured in the borehole at the origin of the drainage easement did not differ significantly from concentrations measured in baseline samples. Contamination extends to at least 60 cm below the soil surface in most of the borehole locations.

Radionuclide Concentrations in Surface Water

Two water samples were collected from the southeast drainage easement. The radionuclide concentrations measured in the drainage water are presented in Table 44. Both samples contained elevated gross alpha and beta concentrations. The sample collected at the origin of the easement had a gross alpha

concentration of 147 pCi/l. The sample collected at the property fenceline had a gross alpha concentration of 159 pCi/l. Isotopic uranium, radium and thorium concentrations measured for both samples indicate that uranium is essentially the only contaminant.

Location #5

Location #5 is a surface drainage ditch leading from the raffinate pits to drainage ditch #4 (Figures 11 and 18).

Direct Measurements

Direct radiation levels measured at 100 m intervals along the drainage ditch are presented in Table 45. Gamma exposure rates were from 6 to 8 μR/h at the surface and 6 to 13 μR/h measured 1 m above the surface.

Direct measurements from areas of elevated surface readings identified in the walkover scan are presented in Table 46. The highest surface gamma exposure rate (45 μR/h) was measured at 202 m from the origin of the ditch.

Radionuclide Concentrations in Sediment

Radionuclide concentration in sediment samples collected at 100 m intervals are presented in Table 47. Uranium-238 concentrations ranged from <1.05 to 6.00 pCi/g; Ra-226 and Th-232 concentrations were from 0.61 to 8.22 pCi/g and 0.61 to 1.24 pCi/g, respectively.

Concentrations of radionuclides measured in sediment from areas of elevated surface contamination are presented in Table 48. Radium-226 concentrations ranged from 0.94 up to 62.6 pCi/g. U-238 and Th-232 levels were within the levels normally encountered in baseline samples.

Radionuclide Concentrations in Surface Water

Radionuclide concentration measured in a water sample obtained at the culvert 22 m from the origin of the ditch are presented in Table 22. Gross alpha concentration was 4.28 pCi/l and gross beta concentration was 3.22 pCi/l.

Location #6

Location #6 consists of approximately 200 m of Ditch #4 beginning at the Bechtel/DOE fenceline (Figures 11 and 19).

Direct Measurements

Direct radiation levels measured at locations identified in the walkover scan of ditch #4 are presented in Table 49. The surface gamma exposure rates were 14 μR/h and 15 μR/h measured at 95 m and 160 m, respectively. The exposure rate did not change significantly after a 1 kg surface soil sample was removed.

Radionuclide Concentrations in Soil from Shallow Boreholes

The radionuclide concentrations measured in two boreholes (at 95 m and 160 m) are presented in Table 50. Uranium-238 concentrations ranged from 40.1 to 123 pCi/g. Thorium-232 and Ra-226 concentrations were within the range normally encountered in baseline samples.

Location #7

Location #7 is an isolated "hot spot" located 1 m to the north of Road #1, 1154 m from the entrance to the Army Reserve Property.

Direct Measurements

Table 51 presents the direct radiation levels measured at this location. A maximum surface dose rate measurement of 500 μrad/h was recorded and the maximum surface exposure rate measured was 290 μR/h.

Radionuclide Concentrations In Soil From Shallow Boreholes

Radionuclide concentrations from a shallow borehole at location #7 indicate that the Ra-226 contamination is confined to the top 15 cm of the soil surface. The maximum Ra-226 concentration measured at this location was 215 pCi/g.

Uranium-238 and Th-232 concentrations did not vary significantly from baseline levels. The results from the analysis of soil samples obtained at Location #7 are presented in Table 52.

Th-230 Analyses on Selected Samples

Thorium-230 analysis was performed on selected samples from areas which had elevated uranium concentrations. Thorium-230 concentrations ranged from 1.39 $\pm$ 0.13 pCi/g to 53.4 $\pm$ 0.8 pCi/g (Table 53).

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of vicinity properties at the Weldon Spring Site are presented in Appendix C. The Department of Energy criteria for residual uranium in soil specified for the Weldon Spring Vicinity Properties, is 60 pCi/g of U-238 above background provided that the isotopic uranium distribution is normal. The exposure rate criteria at 1 m above the surface is 20 μR/h above background or 27 μR/h for the Weldon Spring area. Radiation levels and radionuclide concentrations exceed these guideline values at seven locations.

Exposure rates at 1 m exceed the 27 μR/h criteria at Location #1 and at one sampling point (10 m) of Location #4 (Table 41). Uranium-238 concentrations in soil samples collected from locations of elevated contact radiation levels exceed the maximum concentrations in samples collected at all of the seven contaminated locations. Subsurface soil concentrations exceed the criteria for uranium at Locations #1, 2, 3, 4, and 6. Pieces of metal and rock prevented examination of the depth of contamination below approximately 1 m at Location #1. Simple regression of the data from several sample points within Location #1 indicate that contamination levels will likely decrease to below the DOE criteria for uranium within the first 125 cm of soil. The soil criteria for Ra-226 (5 pCi/g) are exceeded at Locations #5 and #7 to a maximum depth of approximately 1 m. Thorium-230 measured in selected samples from several different locations was found to exceed the guideline of 5 pCi/g at location #1. Uranium concentrations measured in these same samples are orders of magnitude greater then the measured Th-230 concentrations, therefore,

uranium-238 will be the determining guideline factor. Table 54 and Figures 20-25 summarize the areas of residual contamination exceeding the DOE guidelines. The estimated total volume of soil to be removed to meet the guidelines is approximately 6×10^3 m^3.

The two samples of surface water from the southeast drainage easement and one sample from the ditch within Location #1 contained gross alpha concentrations in excess of EPA guidelines (15 pCi/l)[1]. Combined Ra-226 plus Ra-228 concentrations in water samples were less than 5 pCi/l. Isotopic analyses for uranium indicate that the total concentrations of U-234 plus U-238 exceed the measured gross alpha concentrations. When the uranium isotopic concentrations are subtracted from the total gross alpha concentration measurement the values are less than 15 pCi/l. It should be noted that gross alpha measurements are determined by calibrating against an alpha energy which is higher than the actual uranium energy; therefore, the gross alpha measurements will be slightly lower than the total isotopic measurements. The EPA standards are used here for comparison purposes only, because this water does not represent a source of drinking water.

SUMMARY

A radiological survey of the U.S. Army Reserve property located at Weldon Spring, Missouri was conducted at the request of the U.S. Department of Energy. The survey included surface radiation scans, measurements of direct radiation levels, and analysis of radionuclide concentrations in soil and water, both surface and subsurface. In addition, sediment samples from drainage ditches were analyzed and representative buildings (intact and destroyed) were surveyed.

The results of the survey identified seven areas of U-238, Ra-226, and/or Th-232 contamination exceeding DOE guidelines. Subsurface sampling and measurements indicate that contamination is generally limited to the upper 1 m of soil, although contamination at Location #1 may extend to approximately 1.25 m below the surface. Reduction of contamination to guideline levels would require the removal of approximately 6×10^3 m^3 of material. In addition, portions of the wooden loading dock at Location #3 may need to be removed.

Although there are areas of contaminated residues on portions of this property, the contaminants do not currently pose potential health risks to personnel on the property or to the general public. There is evidence that offsite migration of radioactive materials is continuing via the Southeast Drainage Easement and the drainage ditches from the Raffinate Pit and Ash Pond on the adjacent DOE property.

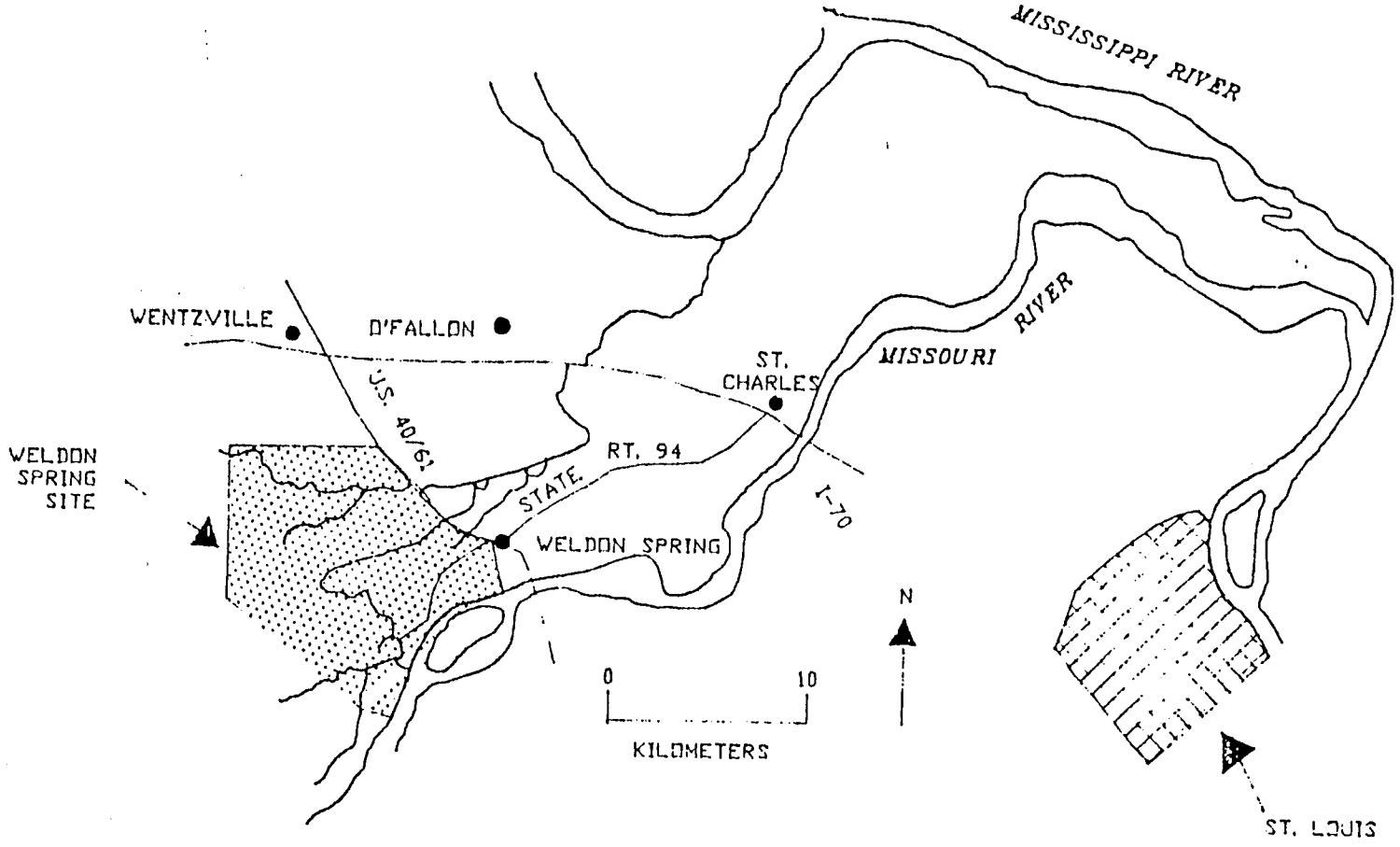

FIGURE 1: Eastern Missouri Indicating the Location of the Weldon Spring Site and Vicinity Properties.

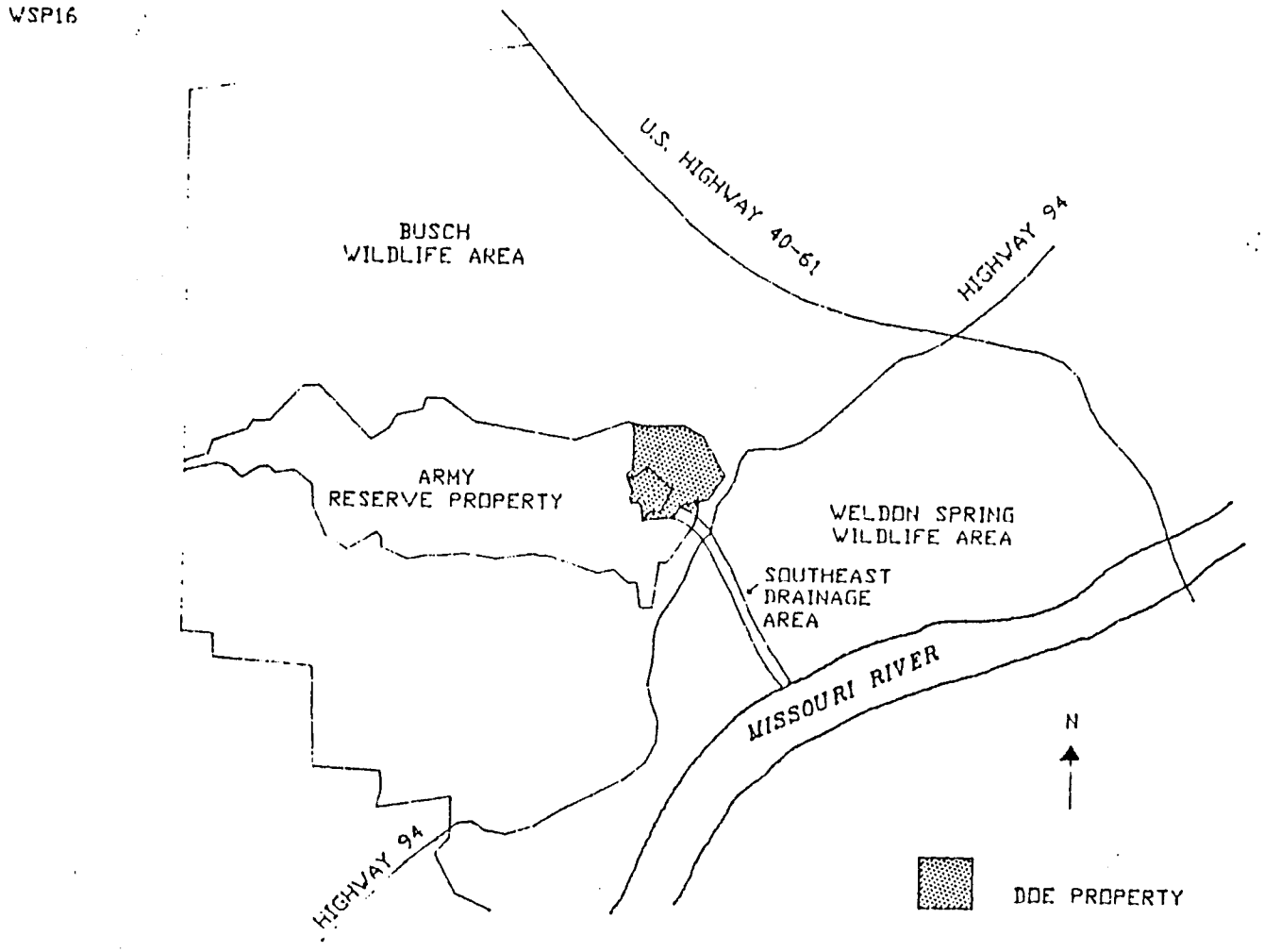

FIGURE 2: Property Bordering U.S. Army Reserve Weldon Spring, Mo.

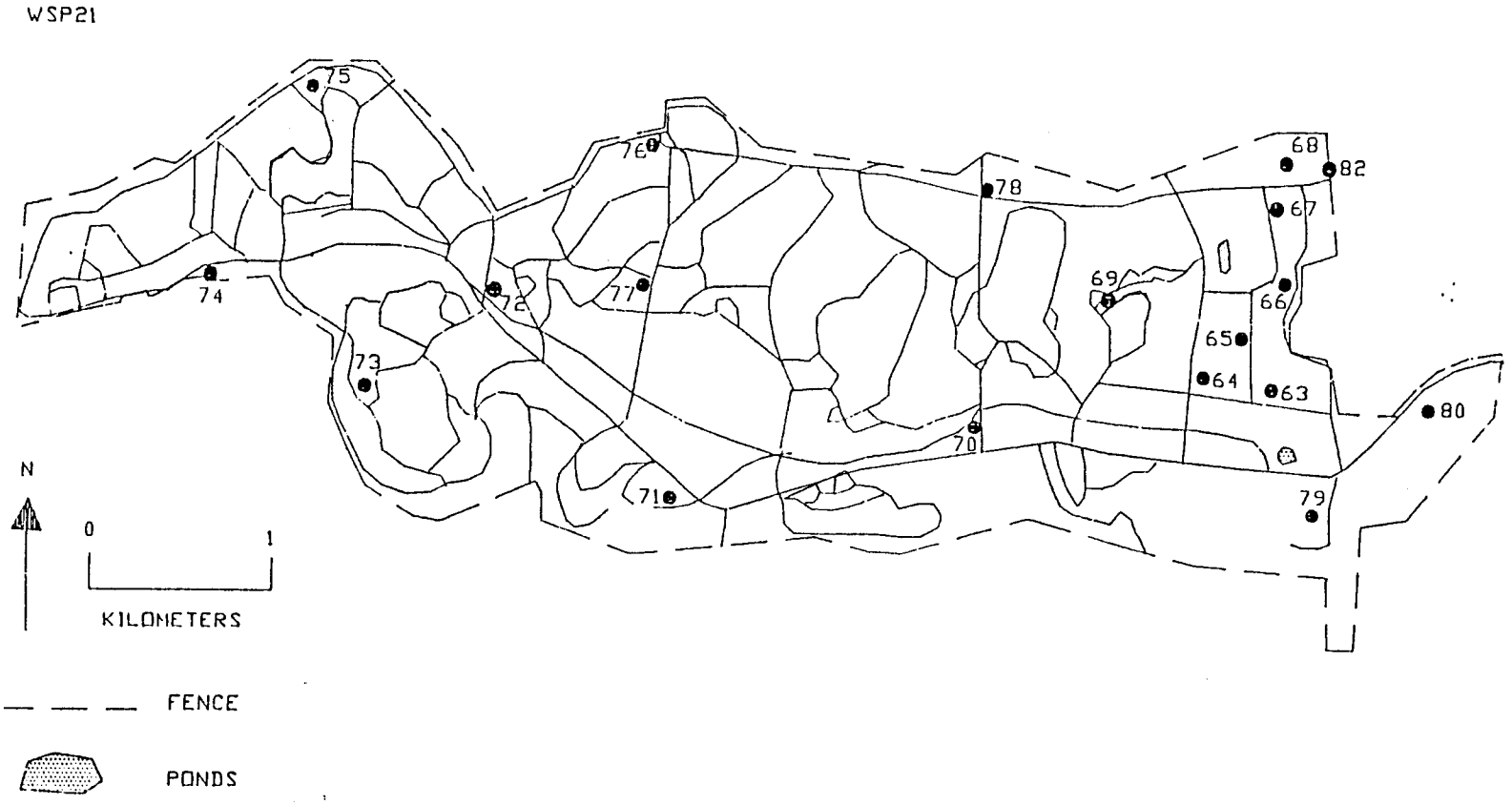

FIGURE 3: Location of Boreholes on Army Reserve Property.

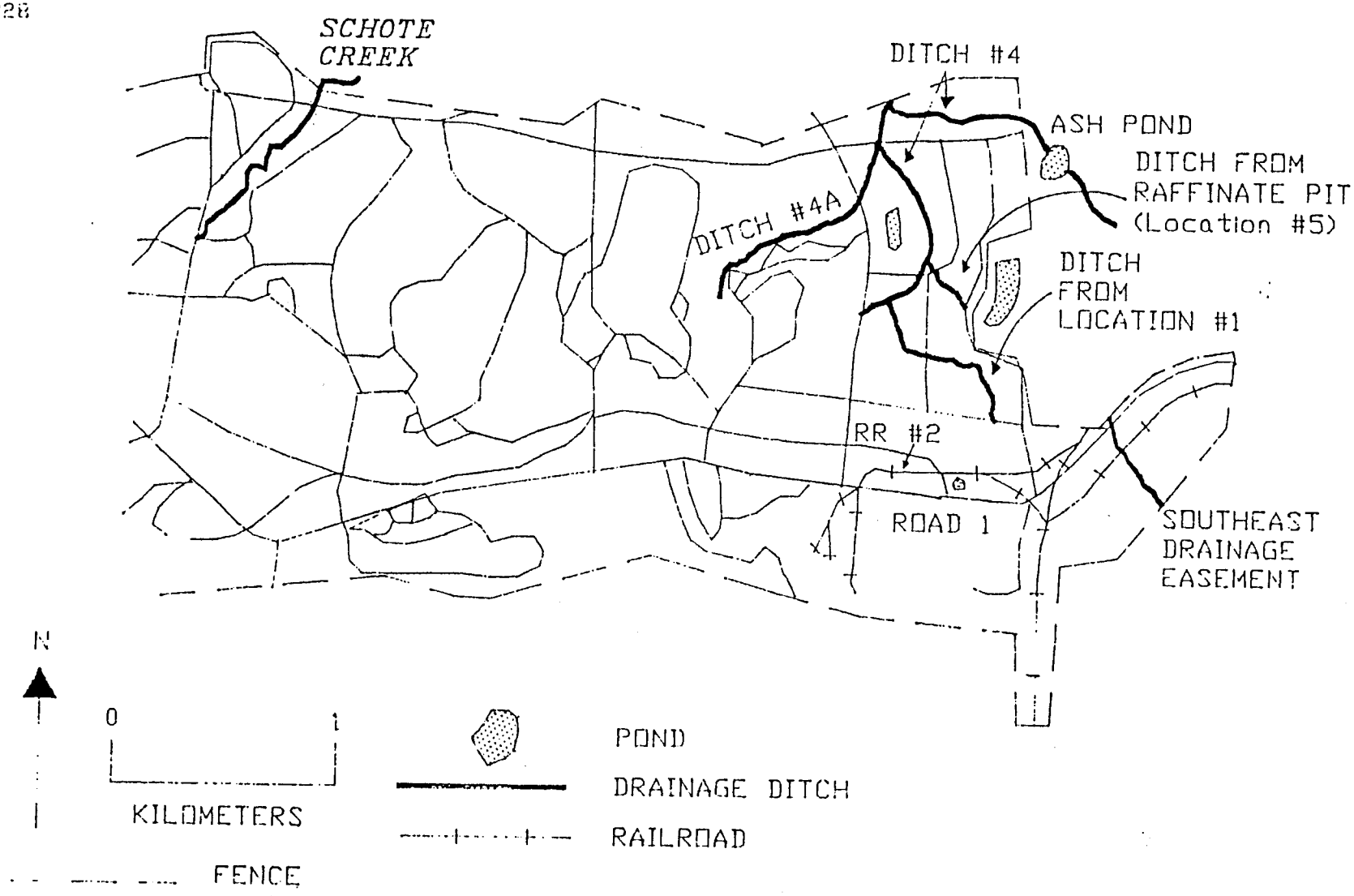

FIGURE 4: Location of Major Surface Drainage Ditches.

FIGURE 5: Location of Buildings on Army Reserve Property.

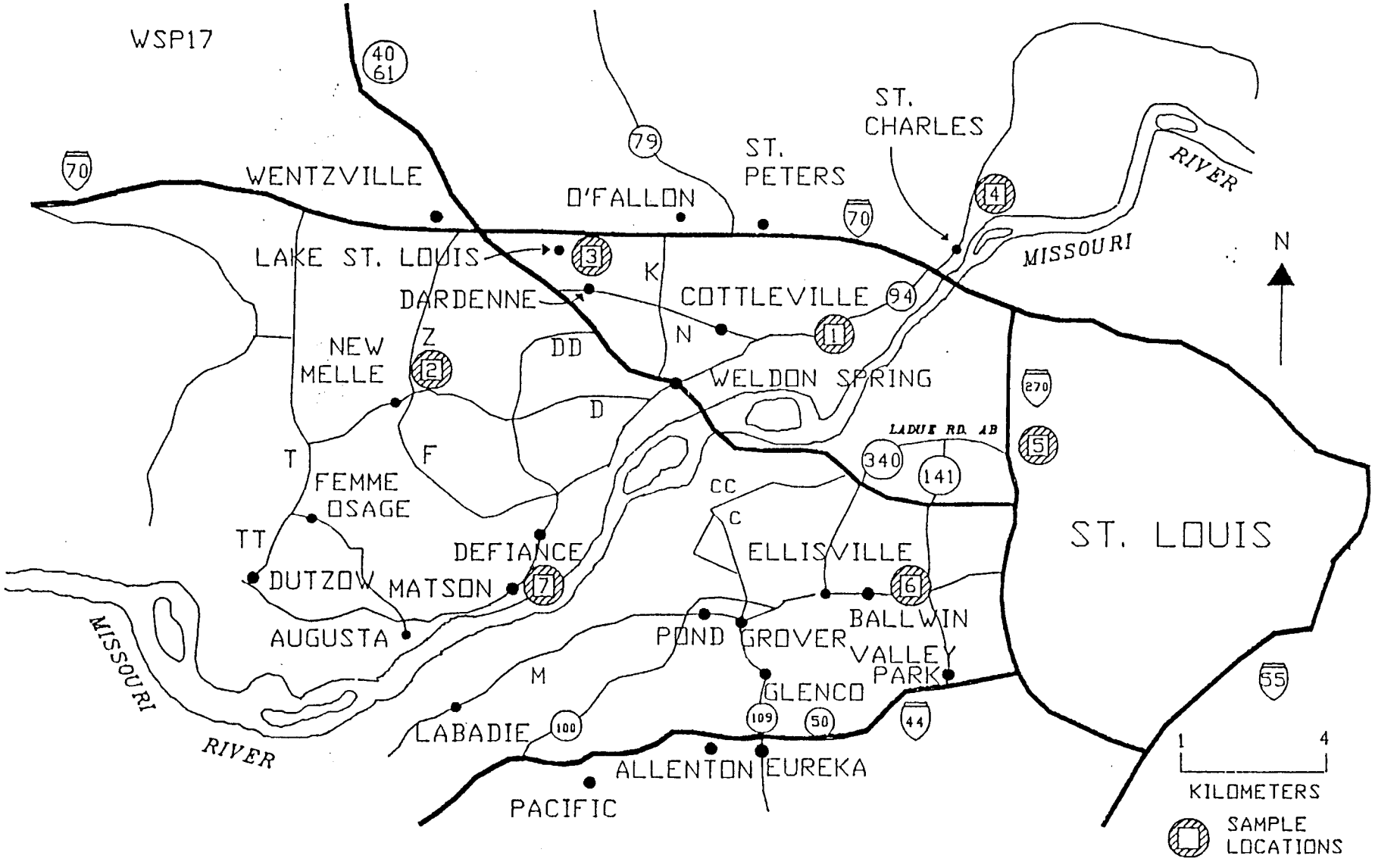

FIGURE 6: Map of St. Louis Area Showing Locations of Background Measurements and Baseline Samples.

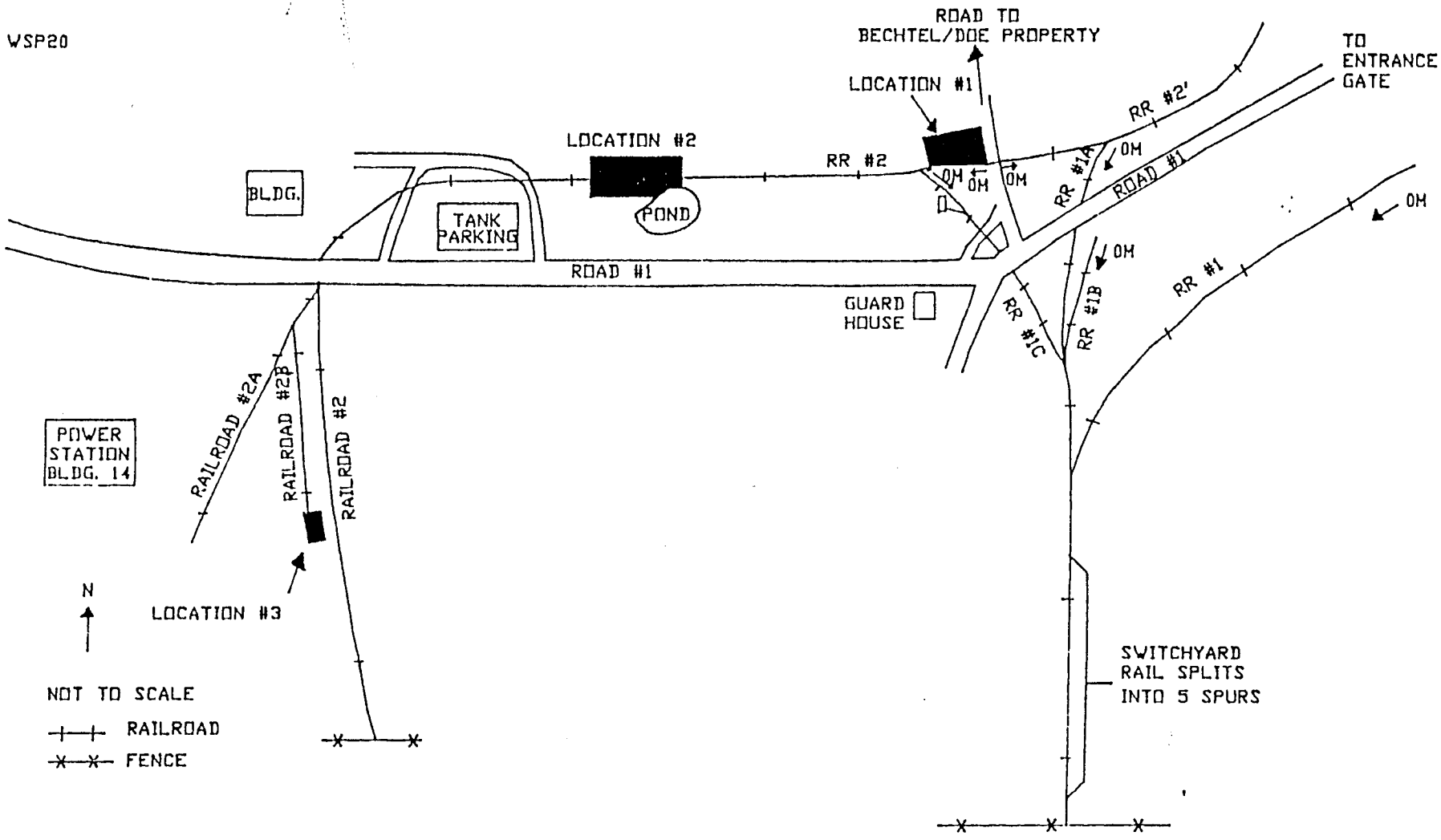

FIGURE 7: Location of Army Railroad #1, #1A, #1B, #1C, #2, #2A, #2B, and #2'.

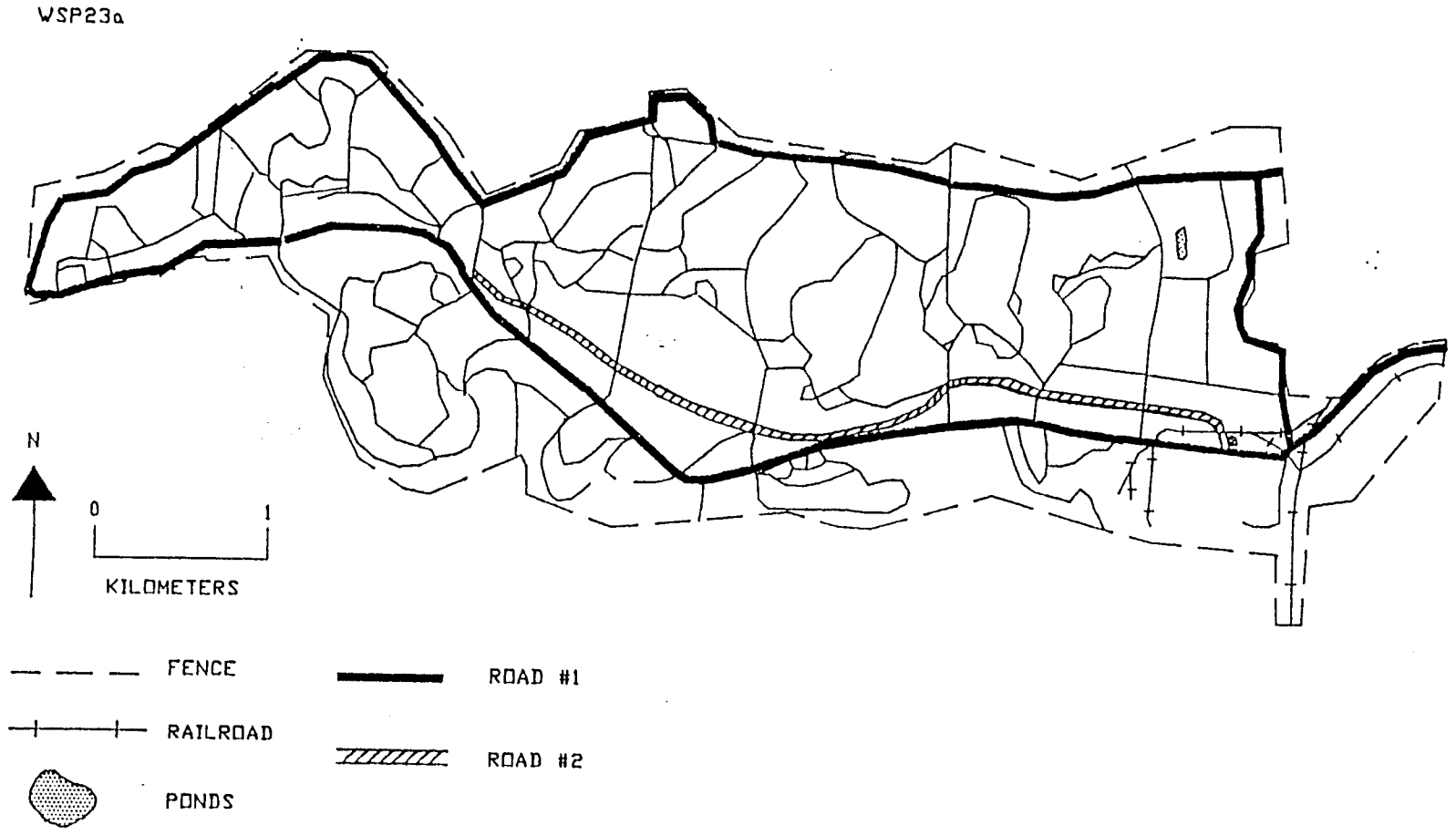

FIGURE 8: Location of Major Roadways on Army Reserve Property.

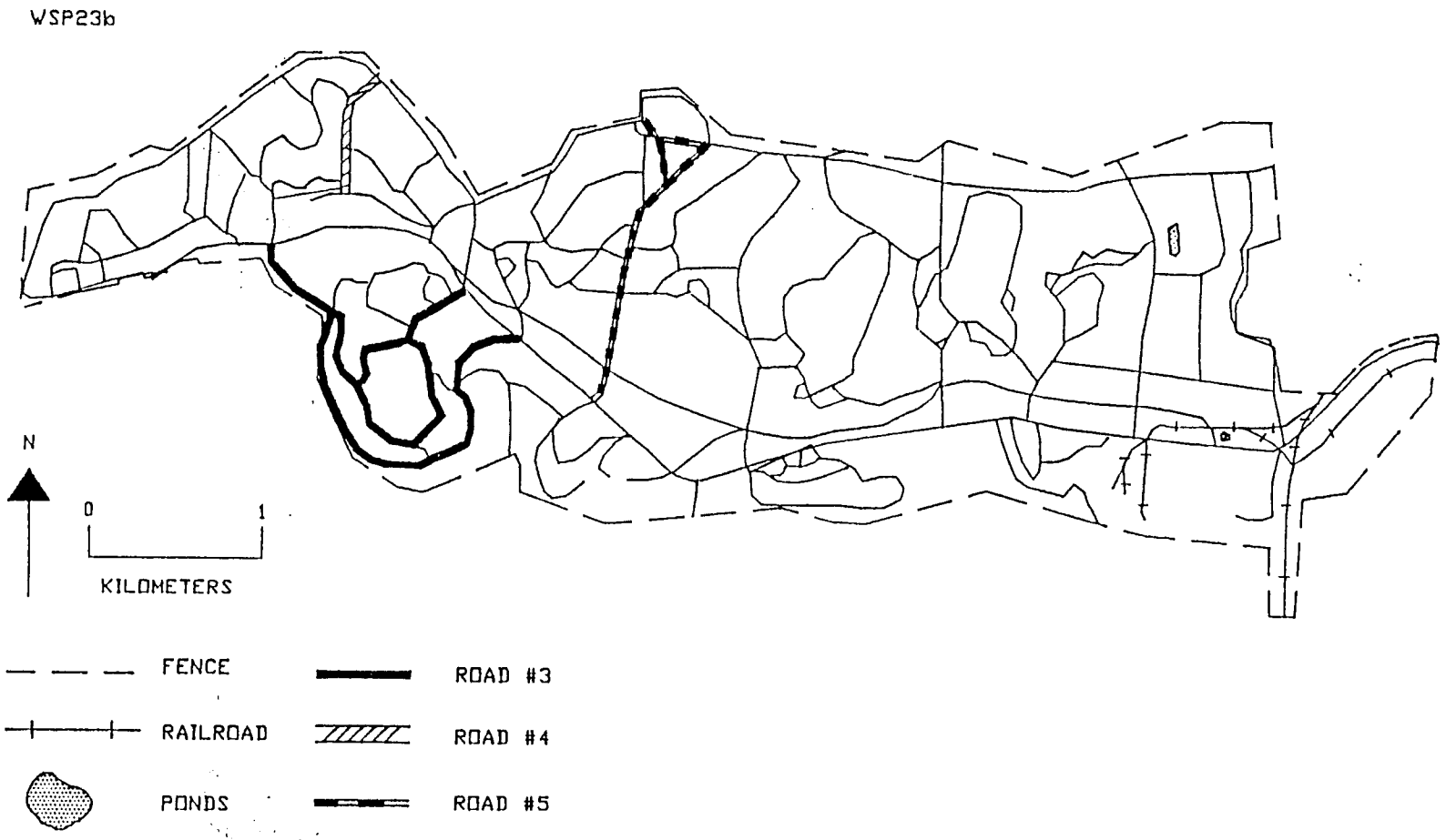

FIGURE 9: Location of Major Roadways on Army Reserve Property.

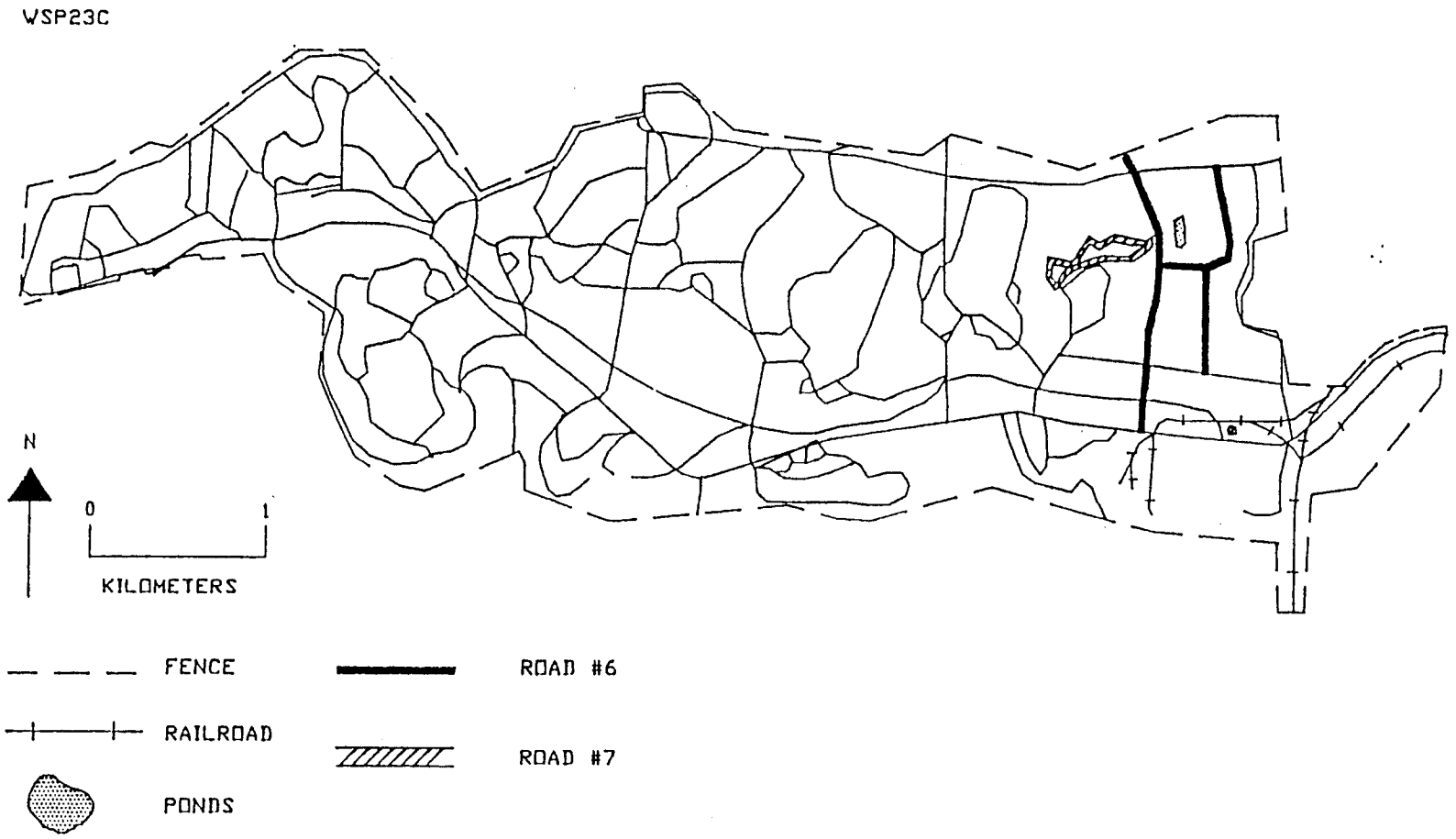

FIGURE 10: Location of Major Roadways on Army Reserve Property.

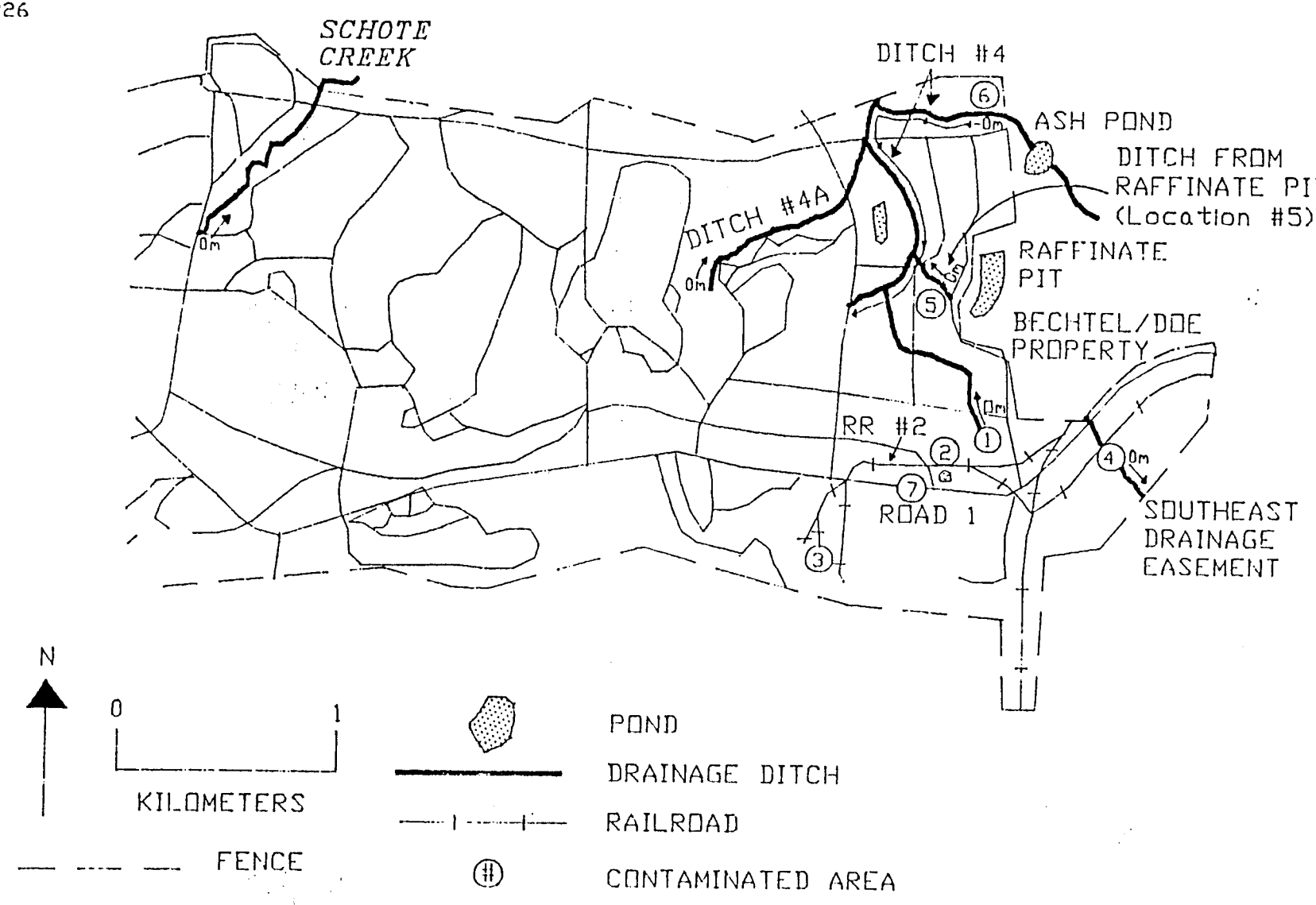

FIGURE 11: Location of Contaminated Areas On Army Reserve Property.

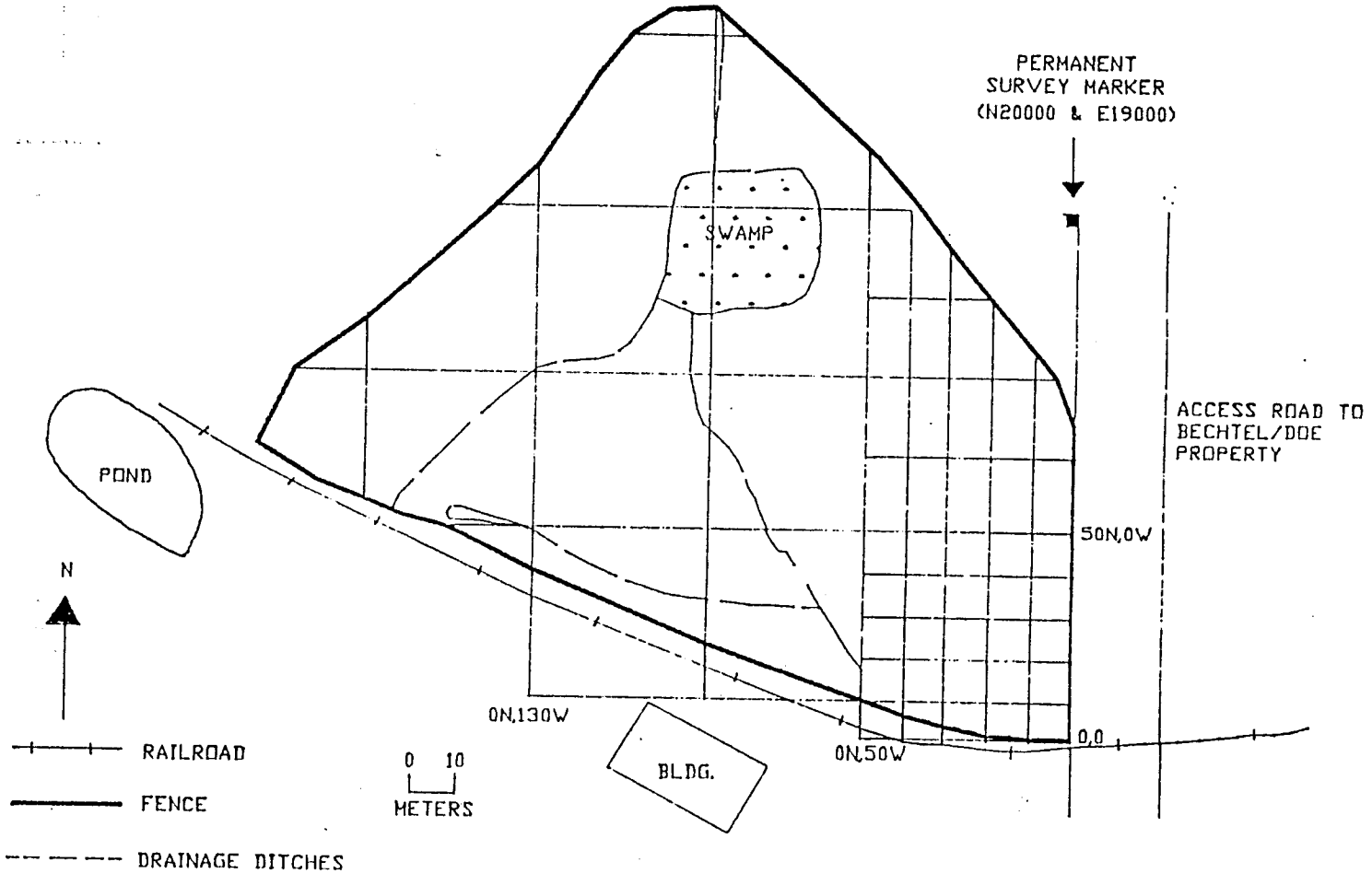

FIGURE 12: Location #1--Grid Established for Survey Reference.

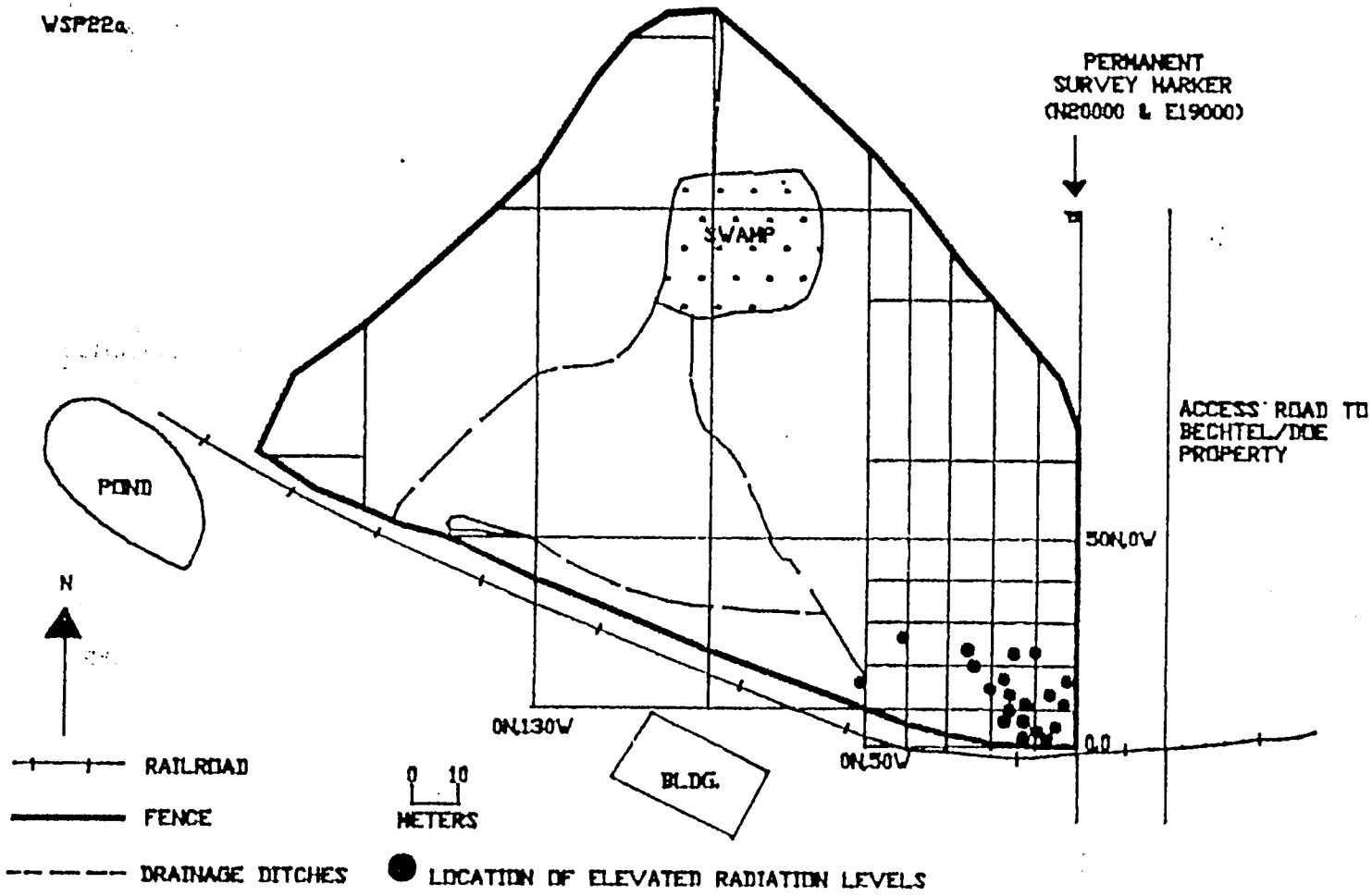

FIGURE 13: Location #1--Locations of Elevated Radiation Identified by Surface Scanning.

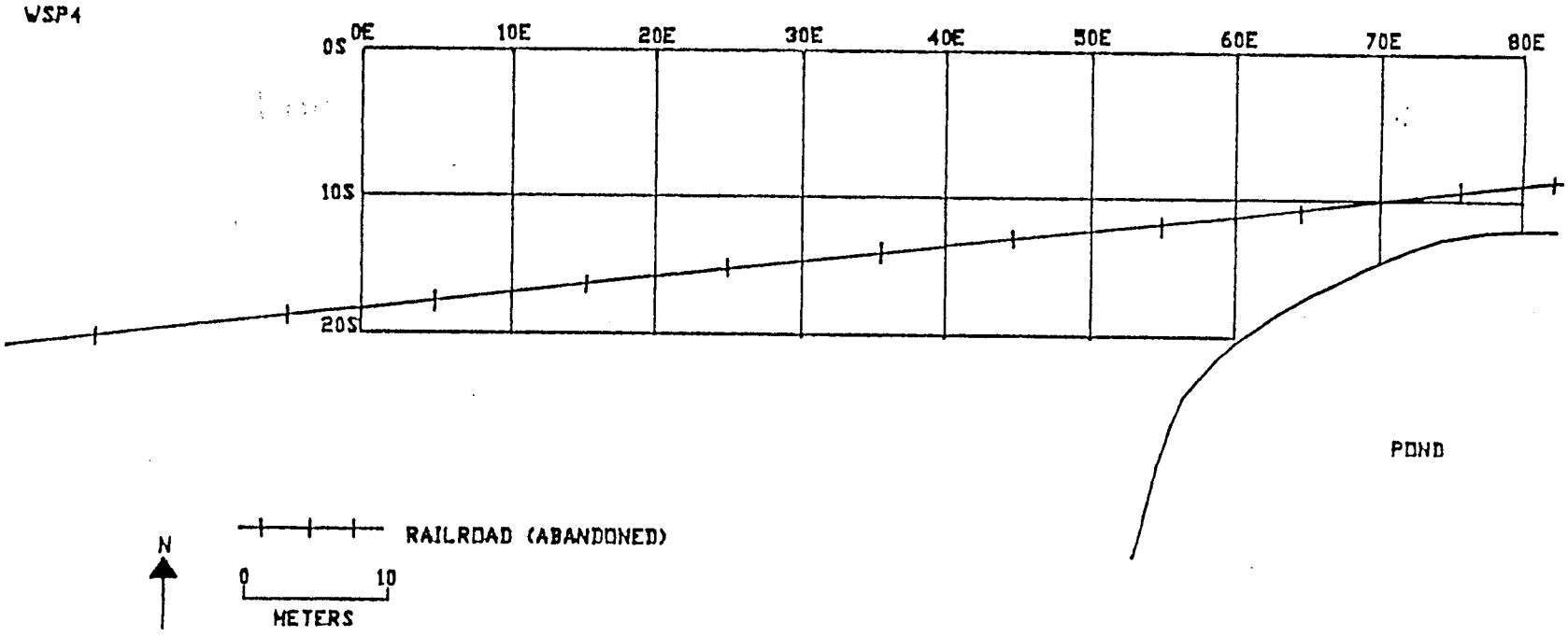

FIGURE 14: Location #2--Grid Established for Survey Reference.

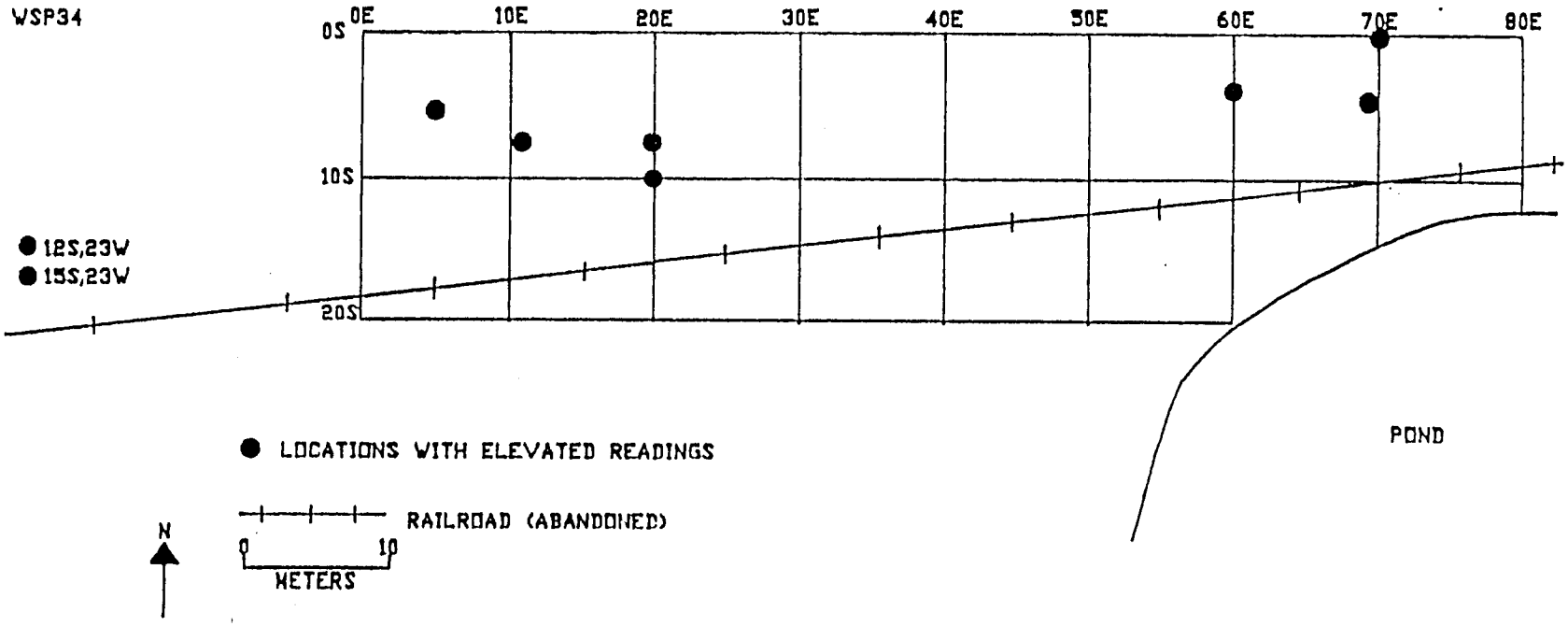

FIGURE 15. Location #2--Locations of Elevated Radiation Identified by the Walkover Scan and Systematic Soil Sampling.

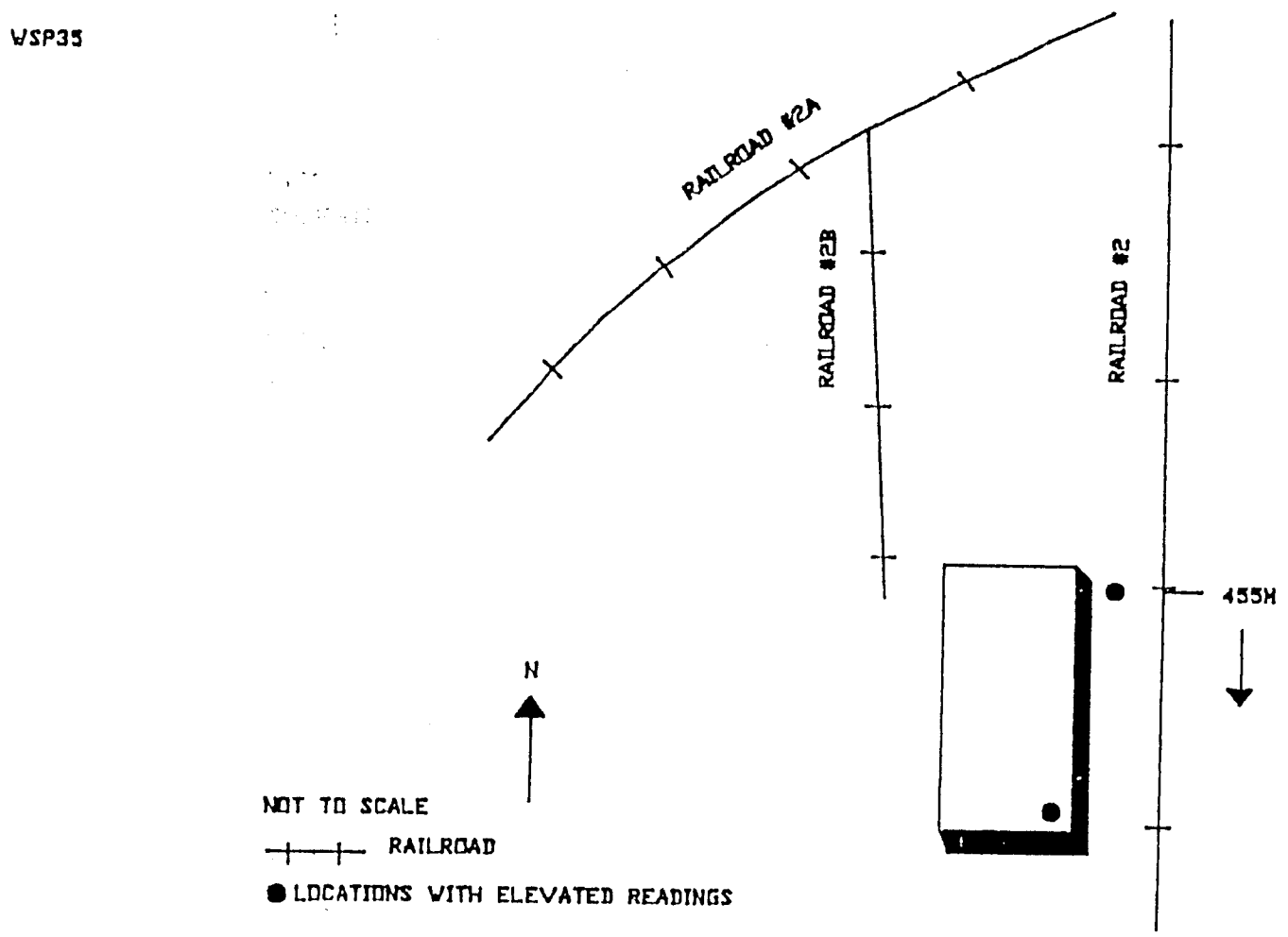

FIGURE 16: Location #3--Loading Dock Area Indicating Locations of Elevated Radiation Identified by the Walkover Scan.

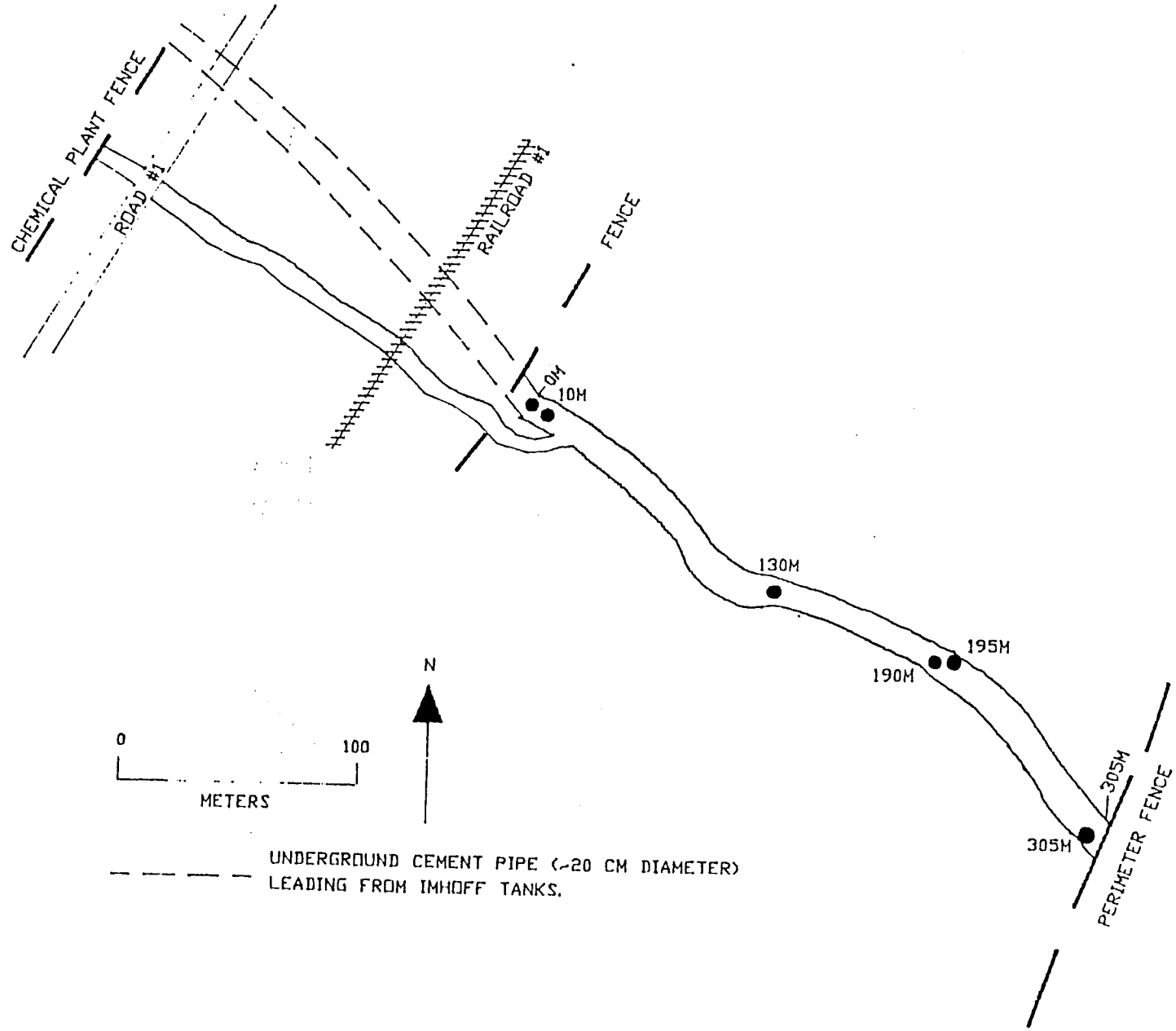

FIGURE 17: Location #4--Southeast Drainage Easement Indicating the Reference Grid and Locations of Elevated Radiation Identified by the Walkover Scan.

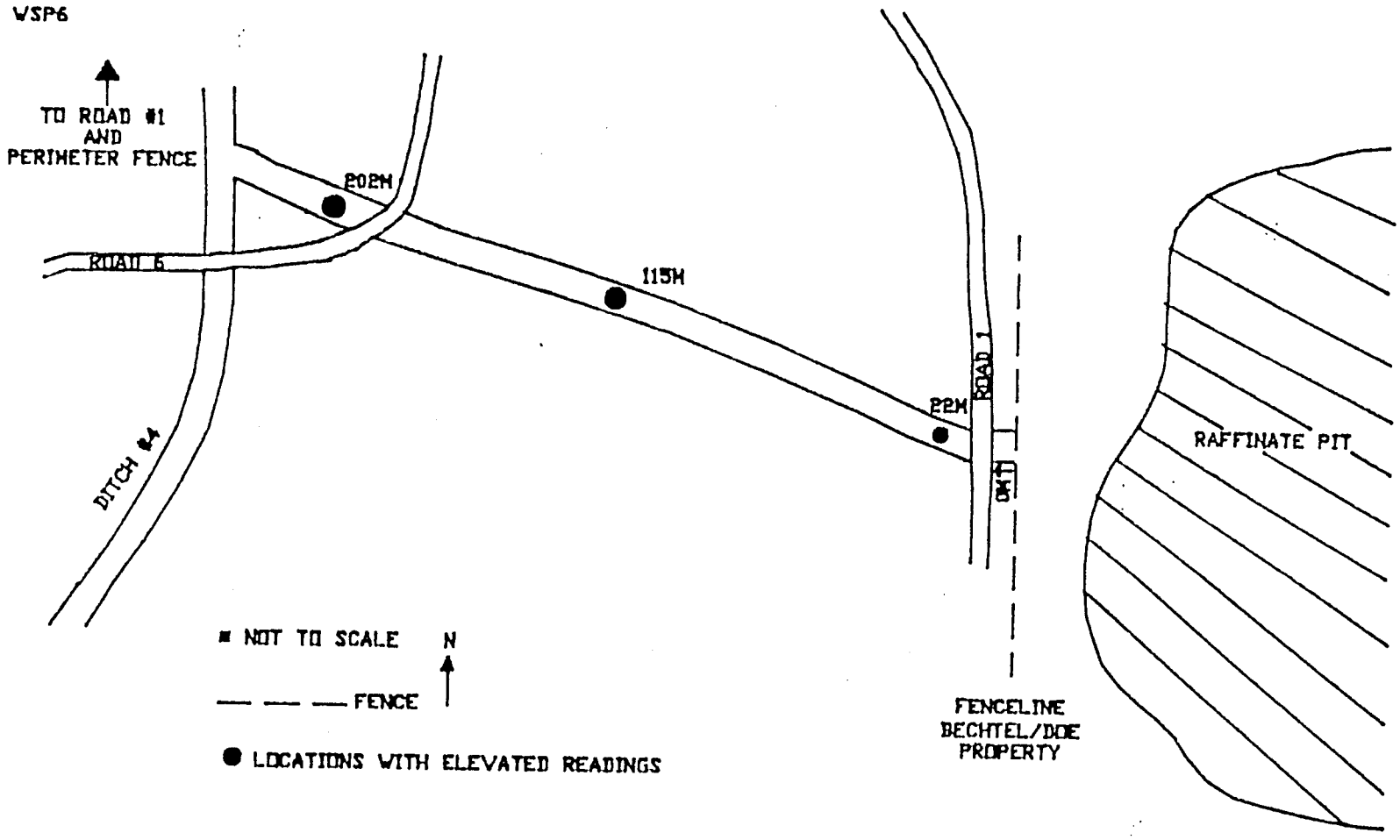

FIGURE 18: Location #5--Drainage Ditch from DOE Raffinate Pit Indicating the Reference Grid and Locations of Elevated Radiation Identified by the Walkover Scan.

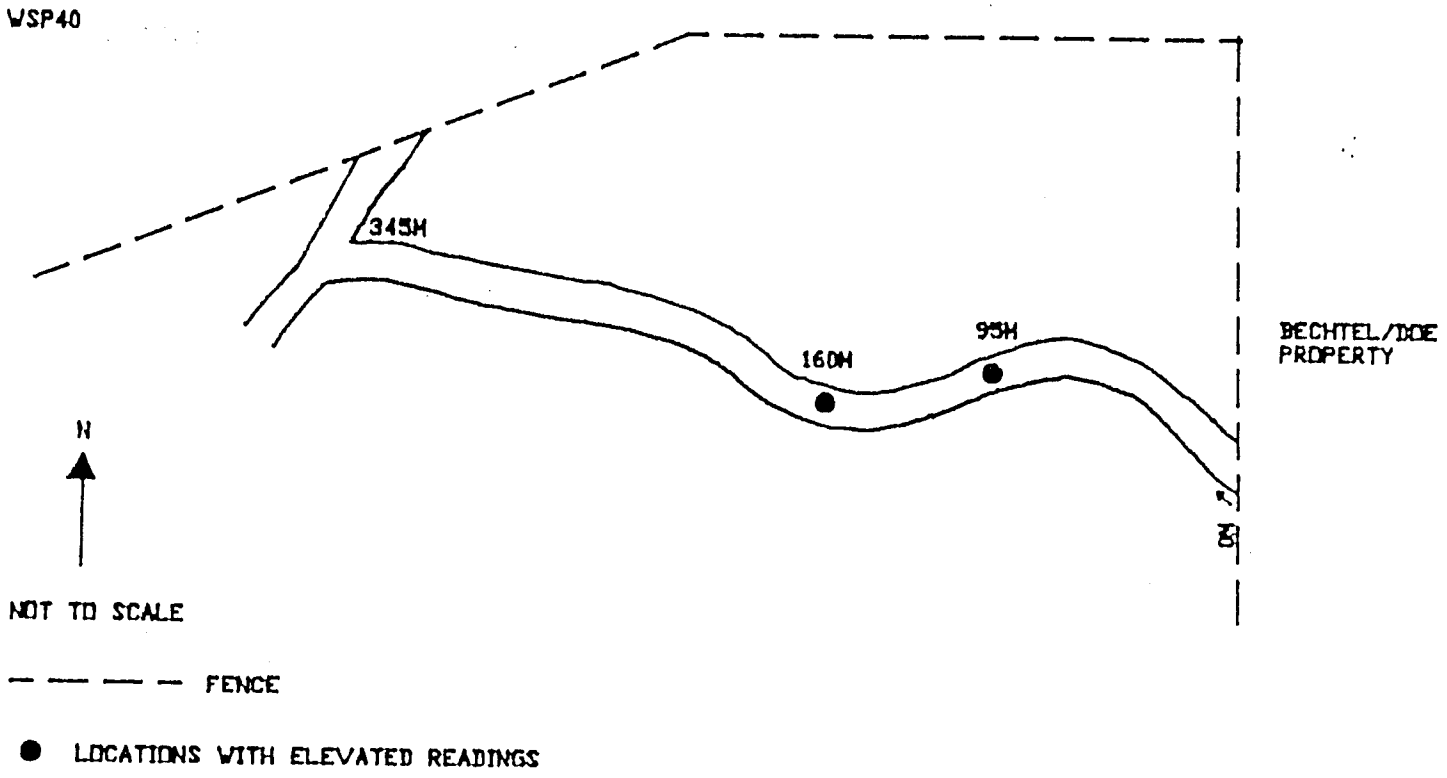

FIGURE 19: Location #6--Drainage Ditch from Ash Pond Indicating Locations of Elevated Radiation Identified by the Walkover Scan.

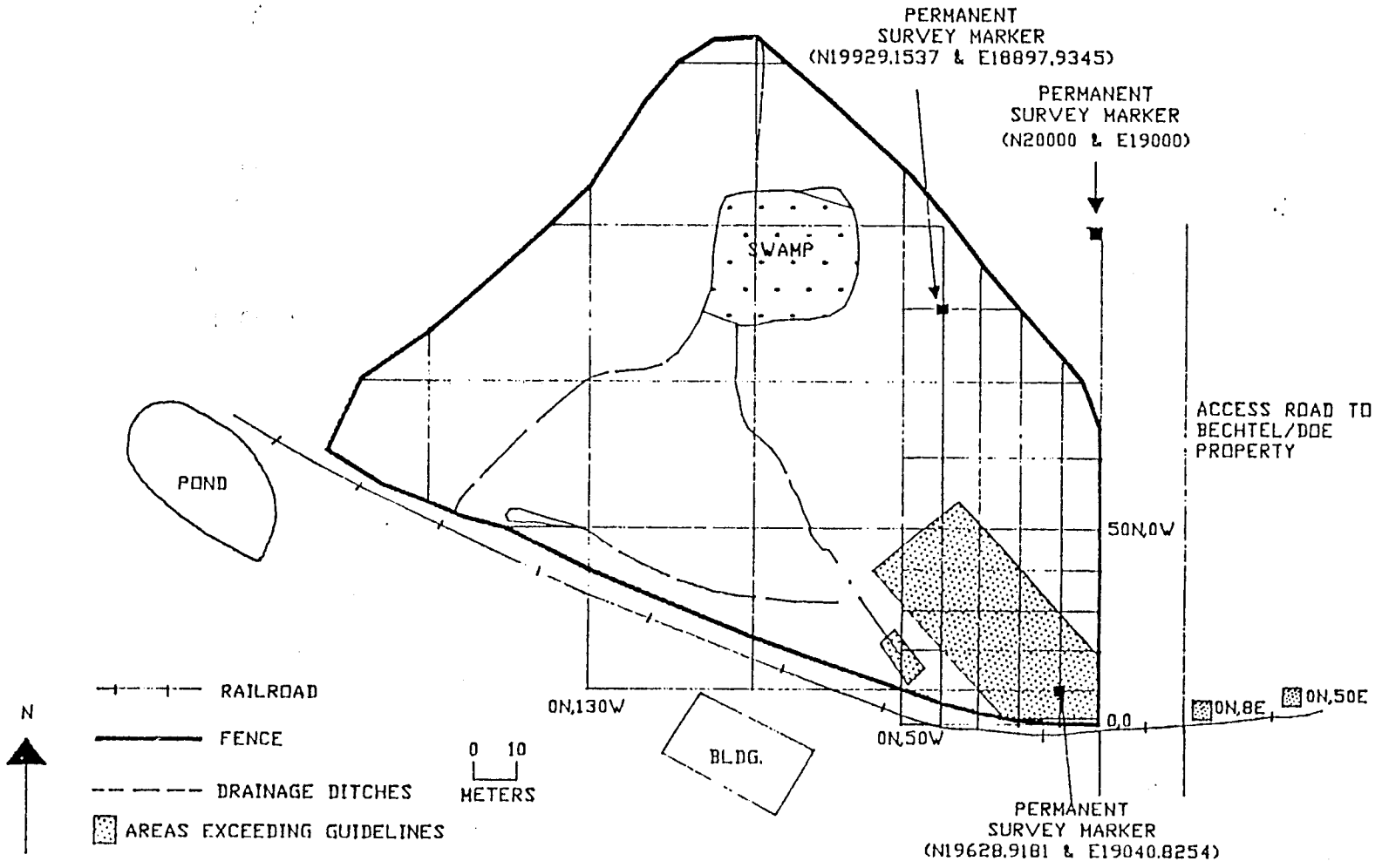

FIGURE 20: Location #1--Areas Which Exceed the DOE Guidelines.

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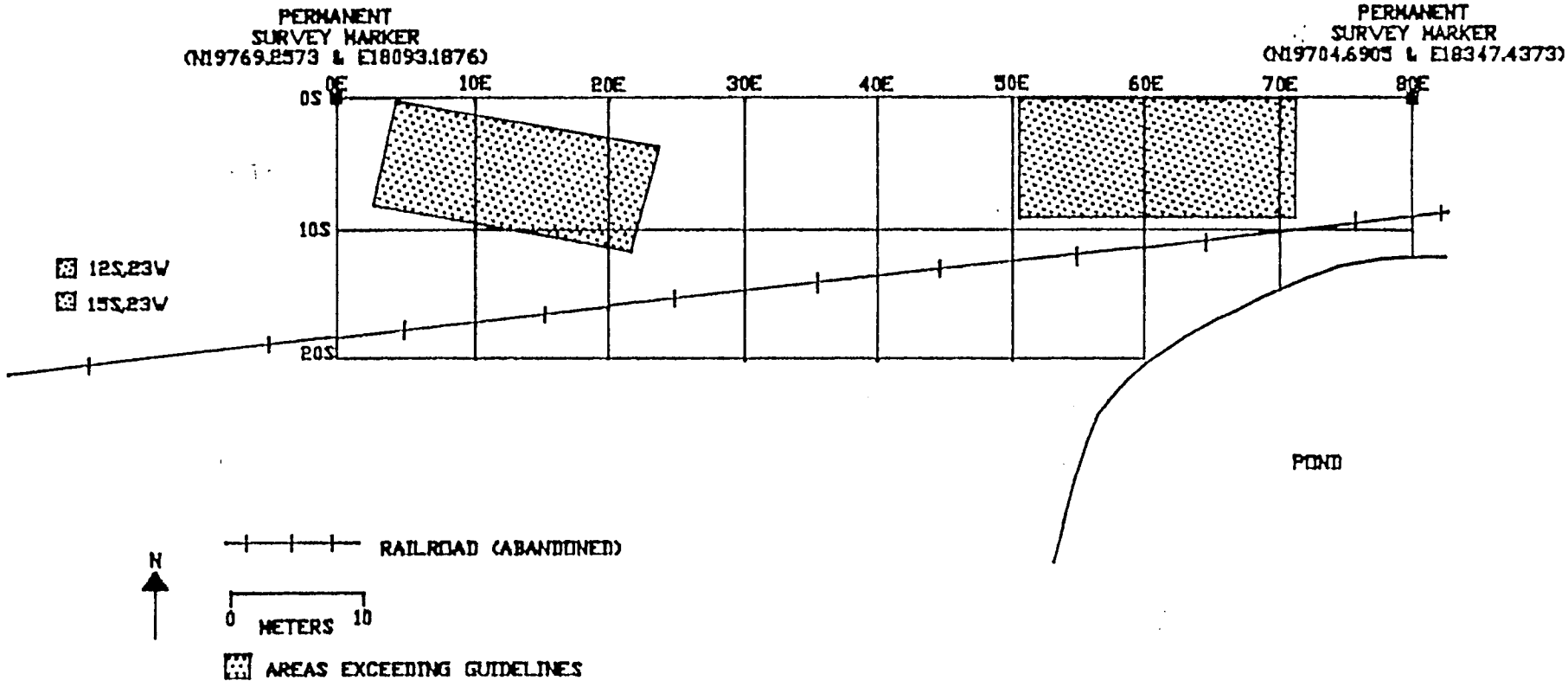

FIGURE 21: Location #2--Areas Which Exceed the DOE Guidelines.

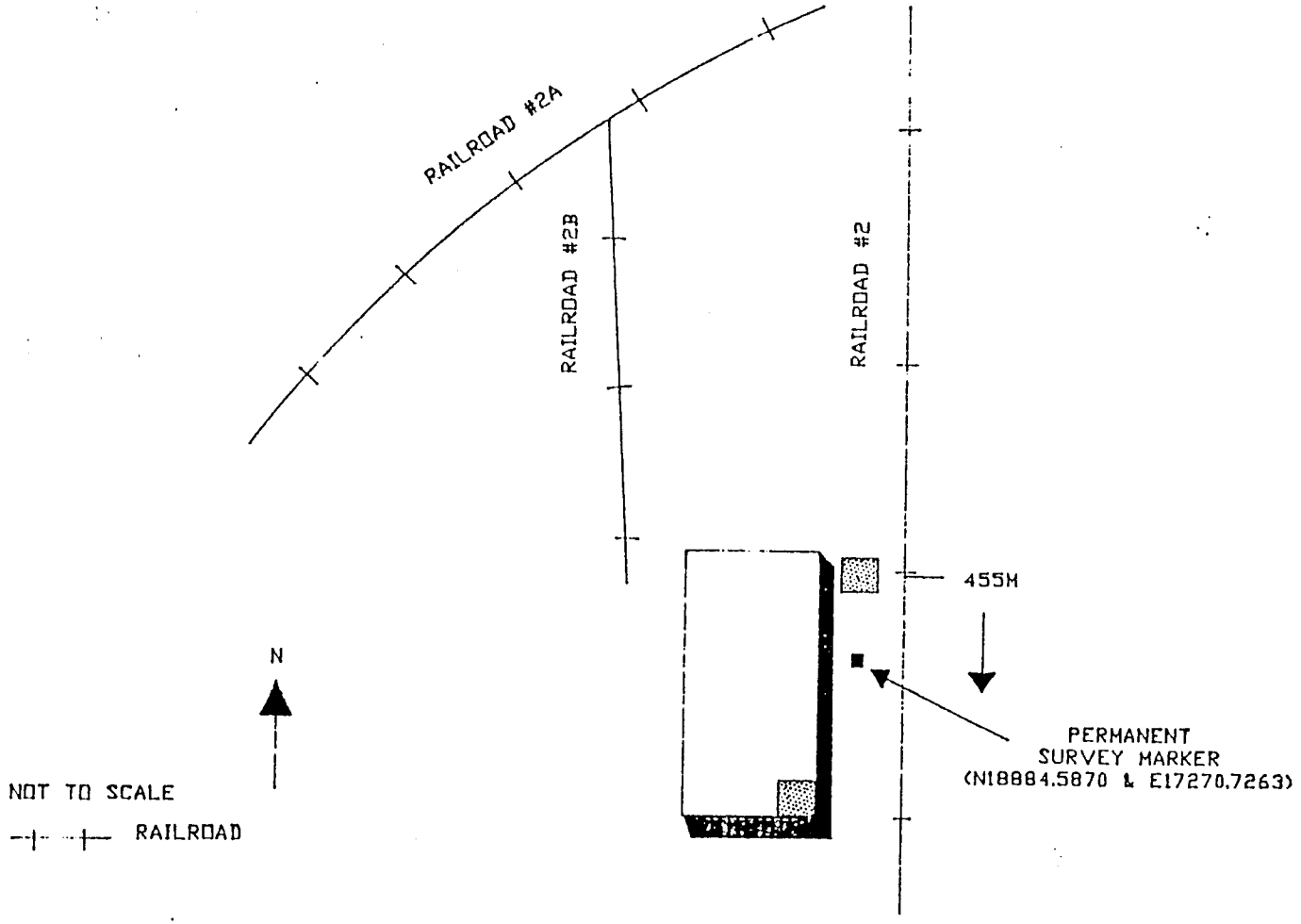

FIGURE 22: Location #3--Loading Dock Areas Which Exceed the DOE Guidelines.

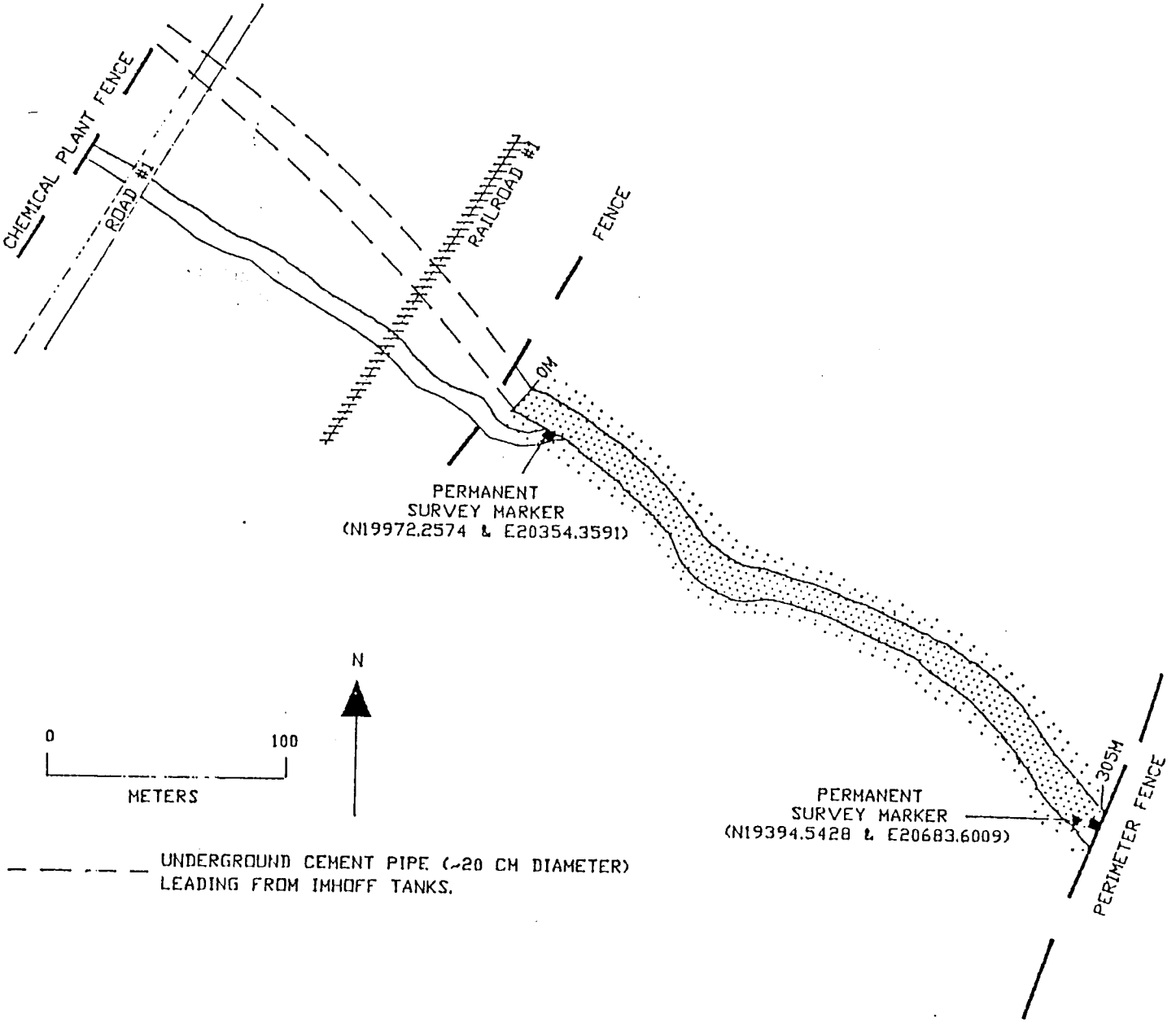

FIGURE 23: Location #4---Southeast Drainage Easement Area Which Exceeds the DOE Guidelines.

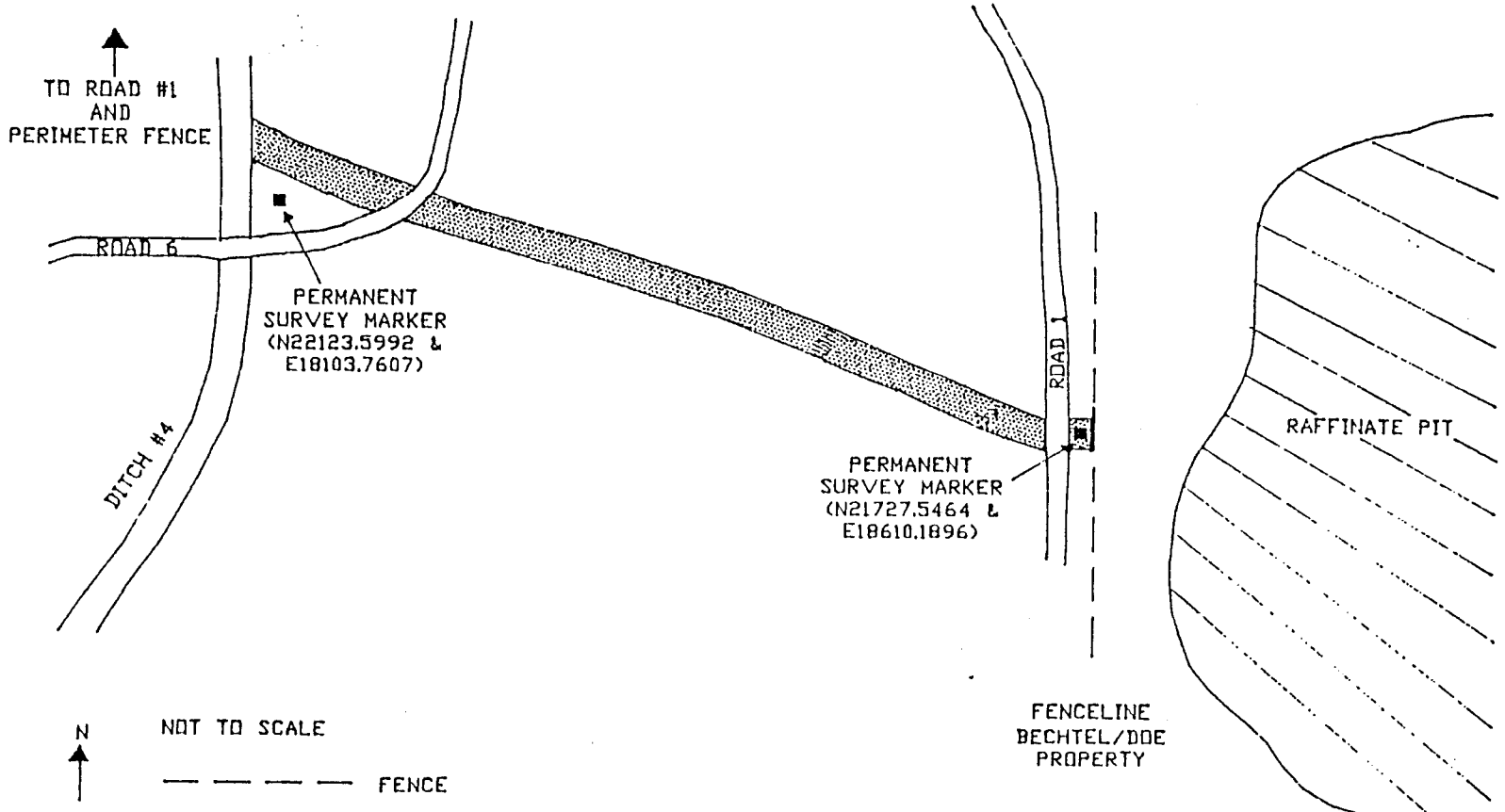

FIGURE 24: Location #5--Area Along the Drainage Ditch from the Raffinate Pit Which Exceeds DOE Guidelines.

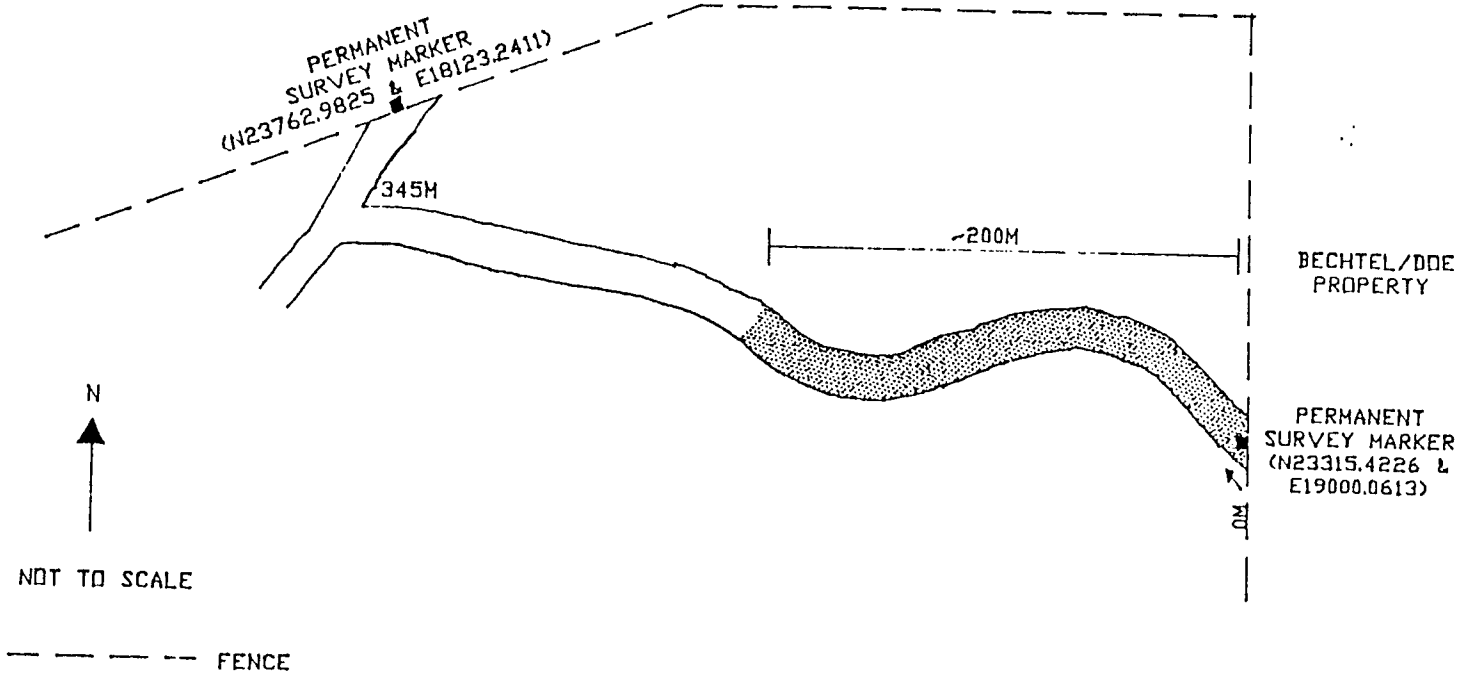

FIGURE 25: Location #6--Area Along the Ash Pond Drainage Ditch Which Exceeds DOE Guidelines.

TABLE 1A

BACKGROUND EXPOSURE RATES AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES
WELDON SPRING, MISSOURI

Location[a]	Exposure Rate[b] (μR/h)	Radionuclide Concentrations (pCi/g)		
		Ra-226	U-238	Th-232
1	7	0.89 ± 0.13[c]	<0.86	1.48 ± 0.21
2	7	0.55 ± 0.13	<0.68	0.97 ± 0.17
3	5	0.71 ± 0.08	1.33 ± 0.74	1.19 ± 0.22
4	7	0.98 ± 0.15	0.87 ± 0.69	0.95 ± 0.26
5	8	0.92 ± 0.12	1.52 ± 0.83	1.48 ± 0.28
6	7	0.69 ± 0.15	1.62 ± 0.99	1.36 ± 0.32
7	6	—[d]	—	—

[a]Refer to Figure 6.
[b]Measured at 1 m above the surface.
[c]Errors are 2σ based on counting statistics.
[d]Dash indicates no sample collected.

TABLE 18

RADIONUCLIDE CONCENTRATIONS IN BASELINE SEDIMENT SAMPLES
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
2	0.73 ± 0.15[b]	<0.83	1.02 ± 0.19
3	0.35 ± 0.06	0.50 ± 0.31	0.24 ± 0.07
4	0.92 ± 0.12	1.38 ± 0.93	0.89 ± 0.20
6	0.62 ± 0.09	<0.60	0.87 ± 0.13
7	0.91 ± 0.09	1.44 ± 0.39	1.02 ± 0.18

[a]Refer to Figure 6.
[b]Errors are 2σ based on counting statistics.

TABLE 1C

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
2	0.86 ± 0.53[b]	3.68 ± 0.95
3	1.05 ± 0.54	4.61 ± 0.99
4	3.19 ± 0.96	7.39 ± 1.13
5	0.48 ± 0.44	3.75 ± 0.94
6	1.02 ± 0.53	3.50 ± 0.94
7	4.09 ± 1.06	6.71 ± 1.11

[a]Refer to Figure 6.
[b]Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
RAILROAD #1
WELDON SPRING, MISSOURI

Location[a] (m)			Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
Main Line				
(#1)	0	C	8	8
	100	L	7	7
	200	R	7	7
	300	L	7	7
	400	L	7	7
	500	R	7	7
	600	C	7	7
	700	L	8	8
	800	R	7	7
	900	C	6	6
#1A	0	L	6	6
	100	R	7	6
	200	C	6	6
	300	L	6	6
	350	R	6	6
#1B	0	C	6	6
	100	R	6	6
	127	L	6	6
#1C	0	L	6	6
	100	R	6	6
	200	L	6	6
	300	R	6	6
Switchyard				
(Spurs)	100	R	6	6
	200	L	6	6
	300	R	6	6
	400	L	6	6
	500	R	6	6
	524	L	6	6

[a]Refer to Figure 7.

TABLE 3

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
RAILROAD #2
WELDON SPRING, MISSOURI

Location[a] (m)			Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
Main Line				
(#2)	100	L	7	8
	200	C	6	6
	300	R	7	7
	400	L	6	6
	500	L	6	6
	600	R	6	6
	630	C	6	6
#2A	0	C	6	6
	100	2L	6	7
	200	R	6	6
	300	C	7	6
#2B	0	R	6	6
	100	L	6	6
#2'	0	L	9	11
	0	R	8	8
	50	L	9	13
	50	R	8	9
	100	L	8	10
	100	R	7	6
	150	L	8	9
	150	R	8	8
	200	L	7	8
	200	R	8	9
	207	L	7	7
	207	R	7	8

[a]Refer to Figure 7.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS - RAILROAD #1
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
Mainline			
0, C	1.34 ± 0.34[b]	8.22 ± 3.16	1.27 ± 0.58
100, L	0.91 ± 0.32	<0.65	<0.20
200, R	0.95 ± 0.36	1.12 ± 1.30	<0.18
300, L	0.50 ± 0.31	1.33 ± 1.54	<0.15
400, L	0.83 ± 0.20	<0.70	0.28 ± 0.27
500, R	0.77 ± 0.29	<0.87	1.10 ± 0.50
600, C	0.74 ± 0.33	<0.79	<0.23
700, L	0.92 ± 0.21	2.28 ± 1.93	1.14 ± 0.35
800, R	0.50 ± 0.29	1.27 ± 1.97	<0.19
900, C	0.88 ± 0.32	1.12 ± 1.40	<0.13
Railroad #1A			
0, L	0.97 ± 0.28[b]	<0.75	<0.20
100, R	0.76 ± 0.41	<0.68	<0.20
200, C	0.81 ± 0.27	<0.58	<0.22
300, L	0.66 ± 0.32	1.19 ± 1.32	<0.16
350, R	1.45 ± 0.31	<0.62	<0.20
Railroad #1B			
0, C	0.29 ± 0.21[b]	<0.57	0.27 ± 0.20
100, R	0.41 ± 0.27	0.82 ± 1.52	<0.18
127, L	0.91 ± 0.31	<0.67	<0.11
Railroad #1C			
0, L	0.46 ± 0.22[b]	<0.62	<0.16
100, R	0.34 ± 0.15	<0.41	0.24 ± 0.17
200, L	0.57 ± 0.23	<0.66	<0.16
300, R	1.58 ± 1.82	1.44 ± 0.81	<0.21
Switchyard Spur A			
100, R	0.83 ± 0.28[b]	<0.73	0.50 ± 0.28
200, L	0.77 ± 0.41	1.38 ± 1.45	<0.19
300, R	0.77 ± 0.30	<0.72	<0.18
400, L	0.93 ± 0.29	1.72 ± 1.29	<0.18
500, R	0.88 ± 0.28	<0.67	<0.43
524, L	0.75 ± 0.46	<0.64	<0.28
Switchyard Spur B			
100, R	0.97 ± 0.37[b]	0.92 ± 1.53	<0.21
200, L	1.09 ± 0.35	1.60 ± 1.39	<0.18
300, R	1.06 ± 0.37	1.78 ± 1.57	<0.17
400, L	0.84 ± 0.28	<0.78	<0.21

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS - RAILROAD #1
WELDON SPRING, MISSOURI

Location	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
Switchyard Spur C			
100, R	0.75 ± 0.31[b]	<0.68	<0.21
200, L	0.57 ± 0.29	<0.67	<0.19
300, R	0.53 ± 0.20	1.49 ± 0.93	<0.23
400, L	0.87 ± 0.34	1.79 ± 1.20	<0.24
Switchyard Spur D			
100, R	0.76 ± 0.41[b]		
200, L	0.48 ± 0.39	<0.76	<0.23
300, R	0.54 ± 0.21	1.04 ± 1.54	<0.16
400, L	0.58 ± 0.29	<0.67	<0.19
Switchyard Spur E			
100, R	0.96 ± 0.30[b]	<0.76	<0.23
200, L	0.66 ± 0.27	1.28 ± 0.90	0.48 ± 0.45
300, R	0.83 ± 0.27	<0.72	<0.18
400, L	0.91 ± 0.28	1.63 ± 1.30	<0.21

[a]Refer to Figure 7.
[b]Errors are 2σ based on counting statistics.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS - RAILROAD #2
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
Mainline			
100, L	1.16 ± 0.33[b]	<1.03	1.51 ± 0.45
200, C	0.46 ± 0.26	<0.76	<0.11
300, R	0.93 ± 0.24	1.51 ± 1.99	0.62 ± 0.28
400, L	0.44 ± 0.17	1.62 ± 1.64	0.40 ± 0.33
500, L	0.78 ± 0.22	1.48 ± 1.17	<0.18
600, R	0.54 ± 0.20	2.04 ± 2.05	<0.21
630, C	0.52 ± 0.21	1.19 ± 1.40	<0.16
Railroad #2A			
0, C	0.90 ± 0.26[b]	1.37 ± 1.81	0.32 ± 0.26
100, 2L	0.39 ± 0.16	3.95 ± 1.84	0.76 ± 0.32
200, R	0.36 ± 0.31	<0.93	0.59 ± 0.32
300, C	0.39 ± 0.35	<1.09	1.41 ± 0.52
Railroad #2B			
0, R	0.69 ± 0.21[b]	2.64 ± 0.91	0.50 ± 0.24
100, L	0.26 ± 0.14	<0.61	<0.13
Railroad #2'			
0, L	0.74 ± 0.28	108 ± 7	1.10 ± 0.39
0, R	1.30 ± 0.27	<0.98	2.20 ± 0.48
50, L	1.16 ± 0.26	143 ± 50	1.39 ± 0.47
50, R	0.68 ± 0.30	3.66 ± 2.29	1.14 ± 0.41
100, L	0.70 ± 0.19	<2.11	1.18 ± 0.48
100, R	0.43 ± 0.23	<0.52	<0.11
150, L	0.64 ± 0.28	28.2 ± 2.9	1.12 ± 0.51
150, R	0.90 ± 0.19	8.37 ± 1.53	1.07 ± 0.47
200, L	0.51 ± 0.21	0.98 ± 1.55	1.01 ± 0.66
200, R	1.02 ± 0.28	14.5 ± 3.3	2.02 ± 0.55
207, L	0.83 ± 0.27	8.23 ± 2.70	1.12 ± 0.52
207, R	0.77 ± 0.30	10.7 ± 3.7	1.69 ± 0.52

[a]Refer to Figure 7.
[b]Errors are 2σ based on counting statistics.

TABLE 6

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #1
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	1R	7	7
100	1L	8	8
200	1R	8	8
300	1L	8	8
400	1R	7	7
500	1L	8	8
600	1R	7	7
700	1L	7	7
800	1R	7	7
900	1L	7	6
1000	1R	6	7
1100	1L	7	7
1200	1R	6	7
1300	1L	6	6
1400	1R	7	7
1500	1L	7	7
1600	1R	7	7
1700	1L	7	7
1800	1R	7	7
1900	1L	7	7
2000	1R	7	7
2100	1R	7	7
2200	1L	8	8
2300	1L	7	8
2400	1L	7	7
2500	1R	7	7
2600	1L	6	6
2700	1R	7	7
2800	1L	7	7
2900	1R	7	7
3000	1L	7	7
3100	1R	7	7
3200	1L	6	7
3300	1R	7	7
3400	1L	7	7
3500	1R	6	6
3600	1L	7	8
3700	1R	7	7
3800	1L	7	7
3900	1R	7	7
4000	1L	7	8
4100	1R	7	7

TABLE 6 (Continued)

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #1
WELDON SPRING, MISSOURI

Location (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
4200	1L	7	7
4300	1R	7	7
4400	1L	7	7
4500	1R	7	7
4600	1L	6	6
4700	1R	7	7
4800	1L	6	7
4900	1R	7	7
5000	1L	7	7
5100	1R	7	7
5200	1L	7	7
5300	1R	7	7
5400	1L	6	7
5500	1R	6	7
5600	1L	7	7
5700	1R	7	7
5800	1L	7	7
5900	1R	7	7
6000	1L	7	7
6100	1R	7	7
6200	1L	7	7
6300	1R	7	7
6400	1L	7	7
6500	1R	7	7
6600	1L	7	7
6700	1R	7	7
6800	1L	6	6
6900	1R	7	7
7000	1L	7	7
7100	1R	7	7
7200	1L	7	7
7300	1R	7	7
7400	1L	7	7
7500	1R	7	7
7600	1L	6	7
7700	1R	6	6
7800	1L	7	7
7900	1R	7	7
8000	1L	7	7
8100	1R	7	7
8200	1L	7	7
8300	1R	7	7
8400	1L	7	7

TABLE 6 (Continued)

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #1
WELDON SPRING, MISSOURI

Location (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
8500	1R	7	7
8600	1L	7	7
8700	1R	7	7
8800	1L	7	7
8900	1R	7	7
9000	1L	7	7
9100	1R	7	7
9200	1L	7	7
9300	1R	6	7
9400	1L	6	6
9500	1R	7	7
9600	1L	7	7
9700	1R	7	7
9800	1L	7	7
9900	1R	7	7
10000	1L	7	7
10100	1R	7	7
10200	1L	7	7
10300	1R	7	7
10400	1L	7	7
10500	1R	7	7
10600	1L	7	7
10700	1R	6	6
10800	1L	7	7
10900	1R	7	7
11000	1L	7	7
11100	1R	7	7
11200	1L	7	7
11300	1R	7	7
11400	1L	7	7
11500	1R	7	7
11600	1L	7	7
11700	1R	7	7
11800	1L	7	7
11900	1R	7	7
12000	1L	7	8
12100	1R	7	7
12200	1L	7	7
12300	1R	7	8
12400	1L	8	7
12500	1R	7	7
12600	1L	7	7
12700	1R	7	7

TABLE 6 (Continued)

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #1
WELDON SPRING, MISSOURI

Location (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
12800 1L	7	7
12900 1R	7	8
13000 1L	8	8
13100 1R	7	8
13200 1L	8	8
13300 1R	7	7
13400 1L	7	7
13500 1R	7	7
13600 1L	8	8
13700 1R	7	7
13800 1L	7	8
13900 1R	8	7
14000 1L	7	7
14100 1R	9	8
14200 1L	7	6

[a]Refer to Figure 8.

TABLE 7

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #2
WELDON SPRING, MISSOURI

Location[a] (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	7	7
100	5	6
200	7	7
300	7	7
400	7	7
500	6	7
600	7	8
700	8	8
800	7	8
900	7	7
1000	7	8
1100	7	8
1200	7	7
1300	7	7
1400	6	7
1500	7	7
1600	7	7
1700	7	8
1800	8	8
1900	7	7
2000	7	7
2100	7	7
2200	7	7
2300	7	8
2400	7	7
2500	7	7
2600	7	8
2700	8	9
2800	8	8
2900	7	8
3000	7	8
3100	8	8
3200	7	7

[a]Refer to Figure 8.

TABLE 8

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #3
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	1L	6	6
100	1R	6	7
200	1L	6	7
300	1R	7	6
400	1L	6	7
500	1R	6	6
600	1L	6	6
700	1R	7	6
800	1L	6	6
900	1R	6	6
1000	1L	7	6
1100	1R	7	6
1200	1L	6	6
1300	1R	6	6
1400	1L	6	7
1500	1R	7	7
1600	1L	7	7
1700	1R	7	7
1800	1L	6	7
1900	1R	7	7
2000	1L	6	6
2100	1R	7	7
2200	1L	6	6
2300	1R	6	6
2400	1L	7	7
2500	1R	7	7
2600	1L	7	7
2700	1R	7	7
2800	1L	7	8
2900	1R	8	8
3000	1L	7	7
3100	1R	6	6
3200	1L	7	6
3300	1R	7	6
3400	1L	6	6
3500	1L	7	7
3600	1R	7	7
3700	1L	6	6

[a]Refer to Figure 9.

TABLE 9

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #4
WELDON SPRING, MISSOURI

Location[a] (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0 1R	7	7
100 .5L	7	7
200 .5R	7	7
300 .5L	7	7
400 .5R	7	7
500 .5L	7	7
600 1R	6	6
700 1L	6	7
717 1R	6	6

[a]Refer to Figure 9.

TABLE 10

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #5
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	1R	7	7
100	1L	6	6
200	1R	6	6
300	1L	7	7
400	1R	7	7
500	1L	7	7
600	1R	7	7
700	1L	7	7
800	1R	7	7
900	1L	7	7
1000	1R	7	7
1100	1L	7	7
1200	1R	6	6
1300	1L	7	6
1400	1R	7	7
1500	1R	7	7
1600	1L	7	7
1700	1R	7	6
1800	1L	7	7
1900	1R	7	7

[a]Refer to Figure 9.

TABLE 27

RADIONUCLIDE CONCENTRATIONS IN H_2O SAMPLES
COLLECTED FROM BOREHOLES
WELDON SPRING, MISSOURI

Borehole[a] No.	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
68	9.10 ± 1.65[b]	17.3 ± 1.6
73	0.60 ± 0.78	2.50 ± 1.09
74	4.85 ± 1.87	9.67 ± 1.76
77	4.75 ± 1.42	5.55 ± 1.25
82	2.05 ± 1.45	11.9 ± 1.5

[a] Refer to Figure 3.
[b] Errors are 2σ based on counting statistics.

TABLE 28

SUMMARY OF SURFACE CONTAMINATION MEASUREMENTS IN BUILDING

BUILDING[a]	SURFACE	TOTAL CONTAMINATION (dmp/100cm^2)		TRANSFERABLE CONTAMINTION (dpm/100cm^2)		GAMMA EXPOSURE RATE (μR/h)
		ALPHA	BETA-GAMMA	ALPHA	BETA-GAMMA	
1	Walls	<56	<570 - 1720	<1	<3	5 - 6
2	Floors Walls/Equipment	<56	<570 - 1000	<1 - 2	<3	5 - 7
3	Walls	<56	<570 - 930	<1	<3	7 - 8
14	Floors Walls	<56 - 150	<570 - 1360	<1 - 2	<3 - 12	5 - 6
15	Floors	<56	<570 - 720	<1	16 - 23	5 - 7
16	Floors	<56	<570 - 720	<1	14 - 21	5 - 6
17	Floors Walls/Equipment	<56 - 90	<570 - 720	<1	6 - 18	5 - 7
18	Floors Walls	<56	<570 - 2220	<1	<3 - 5	6 - 10
19	Floors	<56	<570 - 1650	<1	6 - 26	6 - 10
20	Equipment	<56	<570	<1	11 - 14	5 - 6
21	Floors Equipment	<56	<570	<1	12 - 22	5 - 6

[a]Refer to Figure 5.

TABLE 29

DIRECT RADIATION MEASUREMENTS AT GRID LINE INTERSECTIONS
LOCATION #1
WELDON SPRING, MISSOURI

Grid[a] Location (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
0N 0W	11	9	13
0N 10W	20	8	8
0N 20W	9	6	6
0N 30W	8	7	7
0N 40W	9	9	9
0N 50W	9	9	35
1N 10W b	33	21	1280
2N 20W b	14	8	11
5N 30W b	9	8	8
6N 40W b	8	7	26
9N 50W b	7	7	18
10N 1E	11	11	98
10N 0W	13	9	55
10N 10W	52	56	1010
10N 20W	42	43	880
10N 30W	15	20	360
10N 40W	9	9	9
10N 50W	7	7	7
10N 90W	8	8	21
10N 130W	6	7	21
20N 0W	9	8	48
20N 10W	22	26	720
20N 20W	38	40	1200
20N 30W	20	12	12
20N 40W	12	9	9
20N 50W	11	9	29
25N 90W b	7	6	12
30N 0W	8	8	22
30N 10W	11	9	34
30N 20W	17	22	510
30N 30W	22	17	77
30N 40W	11	9	26
30N 50W	9	9	10
40N 0W	8	8	15
40N 10W	9	9	16
40N 20W	11	9	45
40N 30W	13	16	320
40N 40W	13	15	220
40N 50W	9	9	33
40N 130W	6	6	18
50N 0W	7	7	27

TABLE 29 (Continued)

DIRECT RADIATION MEASUREMENTS AT GRID LINE INTERSECTIONS
LOCATION #1
WELDON SPRING, MISSOURI

Grid Location (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
50N 10W	9	9	25
50N 20W	9	9	19
50N 30W	9	9	29
50N 40W	11	11	69
50N 50W	9	8	18
50N 90W	7	7	23
50N 130W	7	7	37
50N 150W	6	6	6
50N 160W	7	7	9
57N 170W b	6	6	6
70N 0W	4	4	4
70N 1W b	8	8	9
70N 10W	8	9	44
70N 20W	9	9	33
70N 30W	9	9	14
70N 40W	9	9	16
70N 50W	9	9	40
71N 195W b	7	7	7
90N 0W	4	4	4
90N 6W b	8	9	13
90N 10W	8	8	15
90N 20W	9	9	17
90N 30W	9	9	9
90N 40W	9	9	15
90N 50W	9	8	11
90N 90W	7	7	10
90N 130W	7	7	10
90N 170W	7	8	20
90N 187W b	7	7	14
95N 10W b	8	8	8
102N 170W b	8	8	8
106N 20W b	8	9	23
110N 30W	8	8	8
110N 40W	8	9	20
110N 50W	8	8	21
118N 30W b	9	9	26
130N 40W	8	8	18
130N 50W	8	8	24
130N 90W	7	7	7
130N 130W	7	8	9
130N 140W	7	7	22

TABLE 29 (Continued)

DIRECT RADIATION MEASUREMENTS AT GRID LINE INTERSECTIONS
LOCATION #1
WELDON SPRING, MISSOURI

Grid Location (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
139N 130W [b]	7	7	20
142N 50W [b]	8	8	20
170N 90W	7	7	10

[a] Refer to Figure 12.
[b] Measurement taken at fenceline.

TABLE 30

DIRECT RADIATION LEVELS AT LOCATIONS OF ELEVATED SURFACE READINGS
LOCATION #1
WELDON SPRING, MISSOURI

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Contact Exposure[b] Rate After Sample Removal (μR/H)
		Contact	1 m Above Surface		
0N	8E	17	7	610	21
0N	50E	15	8	240	17
2N	8W	82	48	3070	93
2N	14W	410	46	55660	540
4N	9W	150	51	5370	130
6N	5W	200	37	26400	93
8N	14W	>660 [c]	59	3120	>660 [c]
8N	18W	160	42	5350	130
9N	17W	190	43	27790	70
11N	4W	82	48	1480	190
11N	11W	130	53	19900	120
12N	14W	93	40	16830	70
13N	7W	120	42	9780	93
13N	19W	420	34	58850	100
18N	2W	44	15	1130	35
18N	17W	170	37	34120	82
19N	52W	39	14	1180	- [d]
20N	25W	59	42	2300	15
21N	14W	42	30	1810	39
23N	10W	160	15	3480	93
26N	26W	240	37	60460	130
27N	41W	70	20	1790	130

[a] Refer to Figure 13.
[b] Radionuclide concentrations in samples are presented in Table 33.
[c] Observations exceed instrument capability. 1.7 Kg. slag sample collected at this location contained a total U-238 activity of 31 mCi.
[d] No sample collected.

TABLE 31

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM GRID POINT INTERVALS
LOCATION #1
WELDON SPRING, MISSOURI

Grid[a] Location N	W	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
0,	0	0.92 ± 0.24[b]	15.2 ± 2.8	0.31 ± 0.38
0,	10	0.44 ± 0.14	6.07 ± 1.61	0.26 ± 0.33
0,	20	0.42 ± 0.14	1.37 ± 0.69	0.25 ± 0.15
0,	30	0.71 ± 0.27	1.48 ± 1.25	<0.14
0,	40	2.27 ± 0.48	3.16 ± 2.43	2.16 ± 0.63
0,	50	1.03 ± 0.28	9.22 ± 3.09	1.12 ± 0.65
1,	10[c]	6.48 ± 0.62	668 ± 7	2.45 ± 0.63
2,	20[c]	0.71 ± 0.26	6.42 ± 1.83	0.13 ± 0.14
5,	30[c]	0.53 ± 0.17	1.25 ± 1.30	<0.10
6,	40[c]	0.60 ± 0.15	0.86 ± 0.59	0.40 ± 0.20
9,	50[c]	0.85 ± 0.20	2.07 ± 0.80	0.70 ± 0.29
10,	0	1.71 ± 0.30	83.4 ± 2.5	0.72 ± 0.27
10,	10	4.93 ± 0.70	1,100 ± 16	1.01 ± 0.73
10,	20	18.1 ± 1.0	694 ± 11	4.82 ± 0.93
10,	30	1.08 ± 0.33	198 ± 4	1.18 ± 0.42
10,	40	1.27 ± 0.40	<1.24	1.52 ± 0.67
10,	50	1.14 ± 0.24	1.79 ± 0.84	0.68 ± 0.42
10,	90	0.85 ± 0.29	0.92 ± 1.48	1.34 ± 0.58
10,	130	0.64 ± 0.20	1.04 ± 1.17	0.82 ± 0.32
20,	0	1.05 ± 0.26	9.18 ± 2.42	0.55 ± 0.33
20,	10	1.74 ± 0.44	4.15 ± 9	1.48 ± 0.61
20,	20	2.68 ± 0.47	763 ± 10	1.64 ± 0.60
20,	30	0.96 ± 0.32	11.8 ± 2.8	0.88 ± 0.55
20,	40	1.21 ± 0.30	7.62 ± 3.35	0.97 ± 0.41
20,	50	1.00 ± 0.34	<1.17	1.27 ± 0.51
25,	90[c]	0.43 ± 0.17	<0.55	0.31 ± 0.33
30,	0	0.81 ± 0.21	6.96 ± 2.35	0.53 ± 0.27
30,	10	1.23 ± 0.28	13.9 ± 1.6	1.36 ± 0.49
30,	20	1.4 ± 0.45	386 ± 13	0.79 ± 0.56
30,	30	1.28 ± 0.30	224 ± 6	0.98 ± 0.46

TABLE 31 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM GRID POINT INTERVALS
LOCATION #1
WELDON SPRING, MISSOURI

Grid Location N	Grid Location W	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
30,	40	0.97 ± 0.23	0.64 ± 0.66	1.27 ± 0.37
30,	50	1.12 ± 0.28	2.92 ± 2.43	1.25 ± 0.47
40,	0	0.84 ± 0.21	0.60 ± 0.51	0.62 ± 0.42
40,	10	1.00 ± 0.24	4.35 ± 2.00	1.42 ± 0.43
40,	20	1.05 ± 0.34	21.6 ± 3.5	1.12 ± 0.46
40,	30	1.02 ± 0.29	127 ± 5	0.91 ± 0.55
40,	40	0.94 ± 0.45	118 ± 9	0.90 ± 0.90
40,	50	1.23 ± 0.28	2.37 ± 0.96	1.45 ± 0.39
40,	130[c]	0.59 ± 0.23	0.88 ± 1.49	0.48 ± 0.35
50,	0	0.83 ± 0.26	3.71 ± 1.89	0.46 ± 0.44
50,	10	0.86 ± 0.18	4.13 ± 1.12	1.17 ± 0.45
50,	20	1.26 ± 0.25	4.32 ± 0.80	1.14 ± 0.54
50,	30	0.87 ± 0.27	9.54 ± 2.21	0.78 ± 0.65
50,	40	0.90 ± 0.28	44.9 ± 3.7	0.96 ± 0.58
50,	50	1.33 ± 0.32	2.34 ± 2.51	1.21 ± 0.72
50,	90	1.02 ± 0.24	2.26 ± 0.65	1.01 ± 0.34
50,	130	1.09 ± 0.29	3.41 ± 1.12	1.45 ± 0.47
50,	150	0.76 ± 0.22	7.48 ± 2.26	0.30 ± 0.23
50,	160	0.62 ± 0.28	1.44 ± 1.29	0.38 ± 0.24
50,	170	0.85 ± 0.22	0.81 ± 0.66	<0.13
70,	1[c]	0.90 ± 0.22	3.90 ± 1.22	0.71 ± 0.27
70,	10	1.06 ± 0.24	0.97 ± 0.72	1.48 ± 0.35
70,	20	1.28 ± 0.29	3.41 ± 1.98	0.99 ± 0.38
70,	30	0.92 ± 0.27	2.18 ± 1.05	1.28 ± 0.39
70,	40	0.89 ± 0.33	2.47 ± 0.78	0.90 ± 0.40
70,	50	1.15 ± 0.27	7.30 ± 2.30	1.39 ± 0.52
71,	195[c]	0.65 ± 0.22	1.78 ± 1.29	<0.15
90,	6[c]	1.29 ± 0.27	3.49 ± 0.90	1.11 ± 0.34
90,	10	0.83 ± 0.34	2.26 ± 2.96	1.30 ± 0.58
90,	20	1.07 ± 0.28	4.90 ± 1.89	1.23 ± 0.60
90,	30	0.88 ± 0.23	1.45 ± 1.79	1.08 ± 0.38
90,	40	0.84 ± 0.28	3.41 ± 2.77	0.99 ± 0.45
90,	50	1.13 ± 0.22	3.73 ± 0.99	1.45 ± 0.49
90,	90	0.69 ± 0.29	4.15 ± 1.54	0.98 ± 0.65

TABLE 31 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM GRID POINT INTERVALS
LOCATION #1
WELDON SPRING, MISSOURI

Grid Location N	Grid Location W	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
90,	130	1.09 ± 0.33	0.87 ± 0.67	1.68 ± 0.60
90,	170	0.86 ± 0.27	1.56 ± 0.69	1.50 ± 0.56
90,	187[c]	0.90 ± 0.26	2.31 ± 0.96	1.42 ± 0.49
94,	10[c]	1.17 ± 0.29	<1.00	1.35 ± 0.49
102,	70[c]	0.95 ± 0.32	2.97 ± 1.51	1.33 ± 0.46
105,	20	1.07 ± 0.22	5.14 ± 0.94	0.92 ± 0.65
110,	30	1.24 ± 0.36	2.80 ± 1.34	1.11 ± 0.47
110,	40	1.13 ± 0.29	<1.19	1.25 ± 0.50
110,	50	0.43 ± 0.34	6.05 ± 0.28	1.62 ± 0.62
120,	30	1.21 ± 0.52	4.46 ± 2.92	1.04 ± 1.18
130,	40	1.10 ± 0.27	2.70 ± 0.79	1.43 ± 0.55
130,	50	0.89 ± 0.21	1.01 ± 2.83	1.26 ± 0.42
130,	90	1.20 ± 0.41	2.28 ± 2.43	1.24 ± 0.47
130,	130	1.04 ± 0.40	4.25 ± 2.93	1.50 ± 0.65
130,	140	1.05 ± 0.38	1.55 ± 2.92	1.58 ± 1.00
139,	130[c]	1.09 ± 0.27	2.09 ± 0.73	1.03 ± 0.51
142,	50[c]	0.88 ± 0.21	1.80 ± 0.63	1.06 ± 0.55
170,	90	1.02 ± 0.24	2.07 ± 1.47	1.31 ± 0.40
170,	109[c]	1.21 ± 0.22	2.20 ± 1.97	1.57 ± 0.43
176,	90[c]	0.74 ± 0.21	<0.54	0.35 ± 0.22
176,	108[c]	1.19 ± 0.30	2.48 ± 1.20	1.40 ± 0.50

[a] Refer to Figure 12.
[b] Errors are 2σ based on counting statistics.
[c] Samples collected at fenceline.

TABLE 32

RADIONUCLIDE CONCENTRATIONS IN RANDOM SOIL SAMPLES
LOCATION #1
WELDON SPRING, MISSOURI

Grid[a] Location N	Grid[a] Location W	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
40,	10	0-15	1.00 ± 0.24[b]	4.35 ± 2.00	1.42 ± 0.43
40,	10	60	1.22 ± 0.24	1.17 ± 2.68	0.84 ± 0.53
40,	10	90	1.08 ± 0.22	1.49 ± 1.04	1.11 ± 0.63
50,	50	0-15	1.33 ± 0.32	2.34 ± 2.51	1.21 ± 0.72
50,	50	60	1.17 ± 0.23	1.96 ± 0.89	1.11 ± 1.89
50,	50	80	0.96 ± 0.23	2.84 ± 2.41	1.81 ± 0.60
50,	90	0-15	1.02 ± 0.24	2.26 ± 0.65	1.01 ± 0.34
50,	90	60	1.22 ± 0.25	1.86 ± 1.61	1.23 ± 0.57
50,	90	90	1.33 ± 0.24	1.45 ± 0.94	1.40 ± 0.50
70,	30	0-15	0.92 ± 0.27	2.17 ± 1.05	1.28 ± 0.39
70,	30	60	0.99 ± 0.24	<0.88	1.11 ± 0.43
70,	30	90	1.18 ± 0.34	1.91 ± 2.35	0.79 ± 0.57
130,	50	0-15	0.89 ± 0.21	1.01 ± 2.83	1.26 ± 0.42
130,	50	60	0.95 ± 0.24	2.54 ± 1.79	1.31 ± 0.41

[a] Refer to Figure 12.
[b] Errors are 2σ based on counting statistics.

TABLE 33

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN - LOCATION #1
WELDON SPRING, MISSOURI

Grid[a] Location N	Grid[a] Location W	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
2	8	0 - 6	13.7 ± 0.9[b]	2,010 ± 18	4.29 ± 1.02
2	8	30 - 35	10.7 ± 1.1	818 ± 24	2.78 ± 1.28
2	14	0 - 6	12.5 ± 12.7	29,530 ± 220	<10.2
2	14	15 - 25	40.1 ± 1.3	2,430 ± 10	6.85 ± 1.54
2	14	30 - 35	11.1 ± 0.9	986 ± 14	3.10 ± 0.88
2	14	60 - 75	8.04 ± 0.70	1,360 ± 10	2.36 ± 1.10
2	14	90 - 110	2.38 ± 0.46	332 ± 7	1.93 ± 0.51
4	9	0 - 6	3.03 ± 0.71	3,620 ± 20	2.54 ± 0.91
4	9	20 - 30	15.0 ± 0.9	1,430 ± 10	1.52 ± 0.96
4	9	60 - 75	1.15 ± 0.22	77.1 ± 3.3	1.47 ± 0.38
4	9	90 - 105	0.70 ± 0.20	36.0 ± 1.8	1.09 ± 0.40
6	5	0 - 6	4.91 ± 1.83	15,200 ± 100	<1.34
8	14	0 - 15	<4.83	<133	<5.27
8	18	0 - 6	10.8 ± 1.7	666 ± 11	450 ± 6
9	17	0 - 5	17.0 ± 0.8	<25.0	2.31 ± 1.20
9	17	40 - 50	1.10 ± 0.24	2.76 ± 1.16	1.35 ± 0.39
9	17	95 - 100	7.50 ± 0.90	<17.6	2.65 ± 1.14
11	4	0 - 10	2.62 ± 0.63	1,460 ± 20	1.35 ± 0.76
11	4	10 - 15	<6.98	27,890 ± 20	<7.47
11	4	25 - 30	1.36 ± 0.33	131 ± 7	1.36 ± 0.44
11	4	30 - 60	1.08 ± 0.32	82.3 ± 4.6	1.36 ± 0.53
11	11	0 - 10	3.39 ± 0.77	1,780 ± 20	1.73 ± 0.96
11	11	10 - 15	1.87 ± 0.42	608 ± 13	1.34 ± 0.81
11	11	30 - 35	1.26 ± 0.27	57.0 ± 3.2	1.48 ± 0.43
12	14	0 - 7	7.28 ± 0.87	<17.1	2.58 ± 1.11
12	14	45 - 50	0.77 ± 0.30	179 ± 5	0.88 ± 0.42
12	14	90 - 95	1.31 ± 0.30	7.16 ± 1.36	1.12 ± 0.40
13	7	0 - 6	8.35 ± 1.05	948 ± 24	0.83 ± 0.97
13	7	30 - 50	1.32 ± 0.34	136 ± 5	1.51 ± 0.43
13	7	90 - 110	0.88 ± 0.22	17.0 ± 1.39	1.56 ± 0.49

TABLE 33 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN - LOCATION #1
WELDON SPRING, MISSOURI

Grid Location N	Grid Location W	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
13	19	0 - 6	11.3 ± 1.6	19,810 ± 50	1.74 ± 1.68
13	19	60 - 75	1.63 ± 0.33	323 ± 6	1.14 ± 0.44
13	19	90 - 110	2.49 ± 0.34	128 ± 7	1.33 ± 0.63
18	2	0 - 15	0.87 ± 0.42	2,110 ± 30	<0.46
18	17	0 - 10	3.27 ± 1.28	10,650 ± 40	2.44 ± 1.40
18	17	60 - 80	1.04 ± 0.34	61.5 ± 6.5	1.23 ± 0.36
18	17	90 - 110	1.27 ± 0.23	27.0 ± 31.8	1.44 ± 0.47
19	52	0 - 15	1.25 ± 0.75	670 ± 26	1.42 ± 0.65
20	25	0 - 15	1.22 ± 0.58	735 ± 24	0.98 ± 1.21
20	25	65 - 70	1.08 ± 0.31	32.1 ± 3.1	1.49 ± 0.53
21	14	0 - 15	2.93 ± 0.53	1,099 ± 11	1.16 ± 0.77
21	14	60 - 75		48.4 ± 4.5	1.79 ± 0.52
23	10	0 - 15	<1.13	14,260 ± 50	<1.26
23	10	30 - 45	0.88 ± 0.17	186 ± 4	1.37 ± 0.35
23	10	60 - 75	1.37 ± 0.29	13.4 ± 3.3	1.17 ± 0.59
26	26	0 - 15	13.7 ± 2.1	15,020 ± 50	<1.41
26	26	50 - 80	1.08 ± 0.27	39.1 ± 3.6	0.94 ± 0.44
27	41	0 - 15	2.66 ± 1.01	792 ± 28	1.34 ± 1.32
27	41	40 - 55	1.30 ± 0.26	130 ± 4	1.23 ± 0.44
N	E				
0,	8	0 - 10	1.24 ± 0.56	551 ± 10	1.01 ± 0.51
0,	8	0 - 15	1.02 ± 0.28	265 ± 5	0.79 ± 0.55
0,	50	0 - 15	1.04 ± 0.43	139 ± 8	1.11 ± 0.49
0,	50	30 - 40	1.28 ± 0.29	7.04 ± 1.34	1.10 ± 0.39

[a] Refer to Figure 13.
[b] Errors are 2σ based on counting statistics.

TABLE 34

RADIONUCLIDE CONCENTRATIONS IN H_2O SAMPLES
COLLECTED FROM DRAINAGE DITCH - LOCATION #1
WELDON SPRING, MISSOURI

Grid Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
18N, 50W	3073 ± 21[b]	4221 ± 18[c]
38N, 90W	0.90 ± 0.56	6.43 ± 1.09

[a] Refer to Figure 12.
[b] Errors are 2σ based on counting statistics.
[c] Isotopic Uranium levels were:

U-238:	1699	± 29
U-235:	66	± 6
U-234:	1643	± 28
Ra-228:	.20	± .64
Ra-226:	<.08	

TABLE 35

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
COLLECTED FROM DRAINAGE DITCHES - LOCATION #1
WELDON SPRING, MISSOURI

Grid[a] Location N	W	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
18,	43	0.95 ± 0.46[b]	781 ± 13	1.43 ± 0.57
65,	207	0.60 ± 0.15	1.09 ± 0.41	0.48 ± 0.52
70,	170	0.96 ± 0.23	1.74 ± 1.70	11.40 ± 0.62
169,	95	0.97 ± 0.37	2.13 ± 2.22	1.25 ± 0.39
186,	90	1.27 ± 0.27	1.43 ± 1.96	1.32 ± 0.47

[a] Refer to Figure 12.
[b] Errors are 2σ based on counting statistics.

TABLE 36

DIRECT RADIATION LEVELS MEASURED AT GRID LINE INTERSECTIONS
LOCATION #2
WELDON SPRING, MISSOURI

Grid[a] Location		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
S	E			
0	0	7	7	16
0	10	7	7	32
0	20	7	7	39
0	30	8	8	11
0	40	7	7	7
0	50	8	7	66
0	60	14	13	120
0	70	12	11	120
0	80	8	8	21
10	0	8	8	38
10	10	9	9	43
10	20	8	9	70
10	30	8	7	45
10	40	8	8	40
10	50	9	8	31
10	60	8	7	31
10	70	6	6	15
10	80	7	8	8
20	0	7	8	8
20	10	7	8	31
20	20	7	8	18
20	30	7	8	23
20	40	8	8	8
20	50	7	7	37
20	60	7	7	7

[a]Refer to Figure 14.

TABLE 37

DIRECT RADIATION LEVELS AT LOCATIONS OF ELEVATED SURFACE READINGS
LOCATION #2
WELDON SPRING, MISSOURI

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Contact Exposure[b] Rate After Sample Removal (μR/H)
		Contact	1 m Above Surface		
4S	6E	93	12	93	15
4S	59E	53	21	500	51
5S	68E	150	20	4950	70
6S	11E	26	14	400	35
7S	20E	17	8	130	16

[a]Refer to Figure 15.
[b]Radionuclide concentrations in samples are presented in Table 39.

TABLE 38

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 10 M GRID INTERVALS - LOCATION #2
WELDON SPRING, MISSOURI

Location[a]		Radionuclide Concentrations (pCi/g)		
S	E	Ra-226	U-238	Th-232
0	0	1.27 ± 0.28[b]	4.81 ± 1.67	1.05 ± 0.42
0	10	0.80 ± 0.22	3.56 ± 2.21	1.08 ± 0.41
0	20	0.91 ± 0.25	7.15 ± 1.28	0.49 ± 0.23
0	30	1.03 ± 0.25	11.7 ± 2.8	1.16 ± 0.55
0	40	1.00 ± 0.36	11.4 ± 3.2	1.13 ± 0.43
0	50	0.64 ± 0.22	3.29 ± 1.99	<0.18
0	60	1.17 ± 0.25	<2.98	1.02 ± 0.48
0	70	1.23 ± 0.41	97.4 ± 7.2	1.33 ± 0.62
0	80	1.05 ± 0.32	8.31 ± 2.12	1.06 ± 0.41
10	0	1.44 ± 0.29	<1.39	1.27 ± 0.40
10	10	1.52 ± 0.37	32.6 ± 3.0	1.91 ± 0.51
10	20	1.84 ± 0.37	57.0 ± 5.1	0.87 ± 0.43
10	30	0.96 ± 0.24	<2.08	0.87 ± 0.34
10	40	1.31 ± 0.34	33.1 ± 4.6	1.22 ± 0.54
10	50	1.77 ± 0.32	30.9 ± 4.2	1.80 ± 0.49
10	60	1.72 ± 0.33	<1.76	1.28 ± 0.44
10	80	0.97 ± 0.26	1.13 ± 2.31	1.13 ± 0.41
10	70	0.92 ± 0.20	1.19 ± 0.20	0.40 ± 0.45
20	0	1.13 ± 0.26	3.92 ± 1.19	1.34 ± 0.52
20	10	0.97 ± 0.32	3.59 ± 3.35	0.99 ± 0.45
20	20	1.14 ± 0.28	4.85 ± 1.28	1.18 ± 0.37
20	30	1.28 ± 0.27	2.81 ± 0.82	1.02 ± 0.34
20	40	0.87 ± 0.27	<1.04	1.23 ± 0.41
20	50	1.14 ± 0.24	<0.97	0.86 ± 0.32
20	60	1.08 ± 0.21	1.09 ± 0.62	1.33 ± 0.52

[a]Refer to Figure 14.
[b]Errors are 2σ based on counting statistics.

TABLE 39

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN
LOCATION #2
WELDON SPRING, MISSOURI

Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
4S, 6E	0 - 15	38.8 ± 1.3[b]	34.6 ± 4.7	1.28 ± 0.93
4S, 59E	0 - 10	2.86 ± 0.47	937 ± 13	1.17 ± 0.70
	10 - 15	2.36 ± 0.36	411 ± 35	1.25 ± 0.46
	15 - 30	2.23 ± 0.46	400 ± 10	1.79 ± 1.37
5S, 68E	0 - 10	3.72 ± 1.76	1350 ± 33	<1.23
	15 - 30	5.06 ± 0.62	530 ± 12	2.28 ± 0.83
6S, 11E	0 - 10	2.78 ± 0.44	625 ± 10	1.36 ± 0.48
	15 - 30	1.94 ± 0.42	310 ± 5	1.19 ± 0.49
7S, 20E	0 - 10	1.62 ± 0.38	160 ± 6	1.15 ± 0.46
7S, 20E	10 - 15	0.99 ± 0.29	<1.94	0.88 ± 0.39
12S, 23W	0 - 8	6.16 ± 0.55	390 ± 10	0.47 ± 0.51
	8 - 16	2.78 ± 0.36	74.6 ± 5.0	1.17 ± 0.38
15S, 23W	0 - 8	20.4 ± 0.9	<2.16	1.60 ± 0.73
	8 - 16	36.2 ± 1.3	60.2 ± 5.0	<0.53
	16 - 32	17.4 ± 0.8	10.1 ± 2.2	<0.31
	32 - 46	20.8 ± 0.9	32.4 ± 3.5	0.76 ± 0.57

[a]Refer to Figure 15.
[b]Errors are 2σ based on counting statistics.

TABLE 40

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN - LOCATION #3
WELDON SPRING, MISSOURI

Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
455, 2R	0 - 7	3.14 ± 0.68[b]	1683 ± 20	<0.40
455, 2R	7 - 15	1.34 ± 0.58	2640 ± 10	<0.42
455, 2R	15 - 30	0.82 ± 0.40	880 ± 70	<0.23
455, 2R	30 - 45	0.92 ± 0.29	436 ± 15	<0.24
455, 2R	45 - 60	1.28 ± 0.38	477 ± 11	0.58 ± 0.31
Top of loading dock	0 - 6	4.46 ± 0.78	1042 ± 20	<0.46

[a]Refer to Figures 16.
[b]Errors are 2σ based on counting statistics.

TABLE 41

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
S.E. DRAINAGE EASEMENT
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	1L	12	8
0	2L	8	7
10	C	29	120
100	1R	10	14
130	1L	10	44
190	4R	22	43
195	1L	14	25
200	2L	14	15
300	2R	14	16
305	1R	15	29

[a]Refer to Figure 17.

TABLE 42

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL AND SEDIMENT SAMPLES COLLECTED FROM 100 M INTERVALS ALONG THE SOUTHEAST DRAINAGE EASEMENT WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
Soil			
0, L	0.76 ± 0.18[b]	<0.76	0.43 ± 0.18
100, R	5.51 ± 0.45	1.26 ± 3.03	1.66 ± 0.54
200, 2L	2.93 ± 0.38	41.3 ± 4.1	0.87 ± 0.37
300, 2R	8.36 ± 0.54	42.0 ± 2.0	2.69 ± 0.59
Sediment			
0, C	6.57 ± 0.59	39.7 ± 7.0	2.14 ± 0.71
100, C	5.42 ± 0.46	<1.56	2.18 ± 0.48
200, C	4.34 ± 0.53	11.7 ± 3.5	1.41 ± 0.89

[a] Refer to Figure 17.
[b] Errors are 2σ based on counting statistics.

TABLE 43

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES FROM LOCATIONS IDENTIFIED IN THE WALKOVER SCAN - S.E. DRAINAGE EASEMENT WELDON SPRING, MISSOURI

Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
Soil				
0M, 2L	0-15	0.85 ± 0.24[b]	4.20 ± 2.26	0.82 ± 0.44
0M, 2L	15-30	1.02 ± 0.23	2.19 ± 1.37	1.05 ± 0.35
0M, 2L	30-45	0.70 ± 0.19	1.52 ± 0.52	0.98 ± 0.29
0M, 2L	45-60	0.81 ± 0.23	2.10 ± 0.14	0.99 ± 0.10
0M, 2L	60-75	0.71 ± 0.20	4.24 ± 2.30	0.97 ± 0.33
10M, C	0-15	170 ± 2	300 ± 6	13.6 ± 1.91
10M, C	15-30	210 ± 3	1010 ± 17	9.21 ± 2.31
130M, L	0-15	37.5 ± 1.6	231 ± 9	69.1 ± 30.4
130M, L	15-30	68.6 ± 1.6	81.8 ± 5.8	10.9 ± 1.6
130M, L	30-60	32.5 ± 1.4	69.4 ± 5.9	4.95 ± 1.16
190M, 4R	0-15	59.0 ± 1.6	601 ± 11	1.33 ± 0.98
190M, 4R	15-30	31.0 ± 1.1	216 ± 5	1.52 ± 0.90
	30-45			
190M, 4R	45-60	4.07 ± 0.46	181 ± 6	0.88 ± 0.46
195M, L	0-15	20.9 ± 0.9	<3.92	1.28 ± 0.88
195M, L	15-30	12.7 ± 0.8	150 ± 6	0.98 ± 0.75
195M, L	30-45	3.04 ± 0.44	190 ± 6	1.03 ± 0.65
195M, L	45-60	2.04 ± 0.34	<3.77	1.08 ± 0.40
305M, R	0-15	18.1 ± 0.9	5.31 ± 3.52	1.82 ± 1.02
305M, R	15-30	27.2 ± 1.2	66.5 ± 5.2	8.15 ± 1.43
305M, R	45-60	6.87 ± 0.47	25.1 ± 2.2	1.16 ± 0.49

[a] Refer to Figure 17.
[b] Errors are 2σ based on counting statistics.

TABLE 44

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES
COLLECTED FROM THE SOUTHEAST DRAINAGE EASEMENT
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
Origin	147 ± 5[b]	44 ± 2[c]
Fenceline	159 ± 5	39 ± 2[d]

[a] Refer to Figure 17.

[b] Errors are 2σ based on counting statistics.

[c] Isotopic Uranium, Radium, and Thorium levels were:

U-238:	129 ± 4
U-235:	4.95 ± 0.78
U-234:	125 ± 4
Ra-228:	2.06 ± 0.53
Ra-226:	0.50 ± 0.09
Th-232:	0.05 ± 0.06
Th-230:	0.13 ± 0.09
Th-228:	0.08 ± 0.07

[d] Isotopic Uranium, Radium, and Thorium levels were:

U-238:	134 ± 4
U-235:	4.76 ± 0.79
U-234:	128 ± 4
Ra-228:	1.94 ± 0.47
Ra-226:	0.59 ± 0.10
Th-232:	0.04 ± 0.05
Th-230:	0.24 ± 0.11
Th-228:	0.05 ± 0.05

TABLE 45

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
LOCATION #5 - DITCH FROM RAFFINATE PIT
WELDON SPRING, MISSOURI

Location[a] (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0 C	6	6
100 2L	7	8
200 C	13	18
237 C	9	13

[a]Refer to Figure 18.

TABLE 46

DIRECT RADIATION LEVELS AT LOCATIONS OF ELEVATED SURFACE READINGS
LOCATION #5 - DITCH FROM RAFFINATE PIT
WELDON SPRING, MISSOURI

Grid Location[a]		Exposure Rate (μR/h)		Contact Exposure Rate[b] After Sample Removal (μR/h)
		Contact	1 m Above Surface	
22		42	12	- [c]
115	2L	17	8	20
202		45	17	160

[a] Refer to Figure 18.
[b] Radionuclide concentrations of samples are presented in Table 48.
[c] Dash indicates measurement not performed.

TABLE 47

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
COLLECTED AT 100 M INTERVALS ALONG THE DITCH
FROM THE RAFFINATE PITS (LOCATION #5)
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, C	0.61 ± 0.23[b]	1.25 ± 1.50	0.61 ± 0.47
100, 2L	1.18 ± 0.25	<1.05	1.24 ± 0.35
200, C	8.22 ± 0.60	6.00 ± 1.16	1.21 ± 0.51
237, C	1.81 ± 0.37	<1.10	0.87 ± 0.36

[a] Refer to Figure 18.
[b] Errors are 2σ based on counting statistics.

TABLE 48

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT
COLLECTED FROM THE DITCH FROM THE RAFFINATE PIT (LOCATION #5)
WELDON SPRING, MISSOURI

Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
22M, C	0- 6	27.3 ± 0.9[b]	<1.10	0.62 ± 0.94
115M, 2L	0-15	0.94 ± 0.26	1.66 ± 0.76	0.16 ± 0.45
115M, 2L	15-30	2.96 ± 0.52	<1.34	1.32 ± 0.73
115M, 2L	45-60	7.47 ± 0.53	1.60 ± 1.33	1.20 ± 0.55
115M, 2L	60-75	2.31 ± 0.32	2.06 ± 2.09	1.32 ± 0.44
202M, C	0-15	52.6 ± 1.4	<1.78	1.32 ± 0.69
202M, C	15-30	62.6 ± 1.6	<3.42	<0.70
202M, C	45-60	26.7 ± 1.0	<1.30	1.42 ± 0.70

[a] Refer to Figure 18.
[b] Errors are 2σ based on counting statistics.

TABLE 49

DIRECT RADIATION LEVELS AT LOCATIONS OF ELEVATED SURFACE READINGS
LOCATION #6
WELDON SPRING, MISSOURI

Grid Location[a]		Exposure Rate (μR/h)		Contact Exposure Rate[b] After Sample Removal (μR/h)
		Contact	1 m Above Surface	
95	1L	14	7	17
160	1L	15	8	14

[a]Refer to Figure 19.
[b]Radionuclide concentrations of samples are presented in Table 50.

TABLE 50

RADIONUCLIDE CONCENTRATIONS IN SOIL FROM AREAS
IDENTIFIED BY THE WALKOVER SCAN - DITCH #4, LOCATION #6
WELDON SPRING, MISSOURI

Location[a] (m)	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
95	0-15	1.28 ± 0.29[b]	113 ± 6	1.43 ± 0.74
95	15-30	1.09 ± 0.26	<3.38	1.54 ± 0.45
95	45-60	0.84 ± 0.29	40 ± 5	1.11 ± 0.41
160	0-15	1.60 ± 0.38	123 ± 80	1.56 ± 0.72
160	15-30	1.09 ± 0.28	91 ± 7	0.78 ± 0.53

[a] Refer to Figure 19.
[b] Errors are 2σ based on counting statistics.

TABLE 51

DIRECT RADIATION LEVELS AT LOCATIONS OF ELEVATED SURFACE READINGS
LOCATION #7
WELDON SPRING, MISSOURI

Grid Location[a]	Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Contact Exposure[b] Rate After Sample Removal (μR/H)
	Contact	1 m Above Surface		
1154 0.5R	120	14	190	200
1154 1.5R	290	17	500	150

[a]Refer to Figure 11.
[b]Radionuclide concentrations in samples are presented in Table 52.

TABLE 52

RADIONUCLIDE CONCENTRATIONS IN SOIL FROM AREA
IDENTIFIED IN WALKOVER SCAN OF ROAD #1 - LOCATION #7
WELDON SPRING, MISSOURI

Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g)		
		Ra-226	U-238	Th-232
1154, 0.5R	0 - 5	12.0 ± 1.0[b]	<1.19	<0.22
1154, 0.5R	10 - 15	206 ± 3	<4.48	1.41 ± 1.51
1154, 0.5R	30 - 35	1.73 ± 0.41	0.53 ± 1.13	1.24 ± 1.19
1154, 0.5R	60 - 65	1.02 ± 0.21	1.21 ± 1.40	1.29 ± 0.44
1154, 1.5R	0 - 5	215 ± 3	<4.69	<1.05
1154, 1.5R	30 - 35	9.0 ± 1.0	<0.73	0.82 ± 0.42

[a]Refer to Figure 11.
[b]Errors are 2σ based on counting statistics.

TABLE 53

TH-230 AND U-238 CONCENTRATIONS IN SELECTED SOIL SAMPLES
WELDON SPRING, MISSOURI

Location	Depth	Radionuclide Concentrations (pCi/g) U-238	Th-230
Location #1, 4N, 9W	0- 6 cm	3620 ± 20	19.2 ± 0.5
Location #1, 2N, 8W	0- 6 cm	2010 ± 18	53.4 ± 0.8
Location #1, 0N, 8E	0-10 cm	551 ± 10	2.07 ± 0.17
	10-15 cm	265 ± 5	1.39 ± 0.13
Location #4, 1290M	0-15 cm	123 ± 80	2.52 ± 0.18
Location #4, 1450M	0-15 cm	113 ± 6	3.47 ± 0.21
SEDE 195M, 1L	15-30 cm	150 ± 6	11.5 ± 0.38
195M, 1L	30-45 cm	190 ± 6	4.15 ± 0.21

TABLE 54

AREAS OF ARMY RESERVE PROPERTIES WHICH EXCEEDS RESIDUAL CONTAMINATION CRITERIA[a]

LOCATION	LOCATION DESCRIPTION	RADIONUCLIDES	ESTIMATED QUANTITIES OF MATERIAL EXCEEDING GUIDELINES			REMARKS
			AREA(m^2)	DEPTH(m)	VOLUME(m^3)	
1[b]	Army Reserve Access Area to Bechtel/DOE Property	U-238	1520	1.25	1900	Depth estimated from regression of existing data
2[c]	Army Railroad #2	U-238	400	.5	200	
3[d]	Army Railroad #2 Loading Dock	U-238	2	1.0	2	Isolated "hot" spots
4[e]	Southeast Drainage Easement	U-238, Th-232, Ra-226	2500	1.0	2500	Estimated width of contamination is 5m
5[f]	Drainage Ditch From Raffinate Pit Area	Ra-226	750	1.0	750	Estimated width of contamination is 3m
6[g]	Drainage Ditch #4 (near property fenceline)	U-238	600	1.0	600	Estimated width of contamination is 3m
7[h]	Army Reserve Road #1	Ra-226	<.5	<.5	<.5	Isolated "hot" spot

[a]Refer to Appendix C.
[b]Refer to Figure 20.
[c]Refer to Figure 21.
[d]Refer to Figure 22.
[e]Refer to Figure 23.
[f]Refer to Figure 24.
[g]Refer to Figure 25.
[h]Refer to Figure 11.

REFERENCES

1. Title 40, Code of Federal Regulations, Part 141, Interim Primary Drinking Water Standards, Federal Register, July 1976.

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

TABLE 11

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #6
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	R	5	5
100	L	6	6
200	R	7	6
300	L	6	6
400	R	6	6
500	L	6	5
600	R	6	6
700	L	6	6
800	R	6	6
900	L	6	6
1000	R	6	5
1100	L	6	5
1200	R	6	6
1300	L	6	6
1400	R	6	5
1500	L	6	6
1600	R	6	5
1700	L	6	6
1800	R	6	5
1900	L	6	5
2000	R	6	5
2100	L	6	5
2200	R	6	6
2300	L	5	5
2400	R	5	5
2500	L	6	6
2600	R	6	5

[a]Refer to Figure 10.

TABLE 12

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
ROAD #7
WELDON SPRING, MISSOURI

Location[a] (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0 1R	7	7
100 1L	8	8
200 1R	7	8
300 1L	7	7
400 1R	8	7
500 1L	7	8
600 1R	8	8
700 1L	7	7

[a]Refer to Figure 10.

TABLE 13

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #1
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, R	1.32 ± 2.19[b]	6.12 ± 1.50	1.31 ± 0.79
100, L	0.75 ± 0.29	1.40 ± 0.72	0.84 ± 0.29
200, R	0.87 ± 0.22	5.50 ± 2.04	0.99 ± 0.48
300, L	1.37 ± 0.33	6.19 ± 2.39	0.94 ± 0.37
400, R	0.84 ± 0.22	0.31 ± 0.56	0.62 ± 0.26
500, L	0.85 ± 0.31	1.81 ± 1.79	0.45 ± 0.29
600, R	0.51 ± 0.21	<0.73	0.46 ± 0.37
700, L	0.62 ± 0.17	1.17 ± 0.53	0.43 ± 0.21
800, R	0.75 ± 0.22	<0.62	0.38 ± 0.54
900, L	0.65 ± 0.20	<0.77	0.41 ± 0.32
1000, R	0.34 ± 0.17	0.79 ± 0.68	<0.10
1100, L	1.20 ± 0.29	2.77 ± 1.29	1.47 ± 0.56
1200, R	1.26 ± 0.29	3.00 ± 2.19	1.50 ± 0.45
1300, L	0.69 ± 0.53	1.04 ± 0.71	0.25 ± 0.18
1400, R	0.69 ± 0.22	1.94 ± 1.54	0.60 ± 0.42
1500, L	0.75 ± 0.38	1.40 ± 0.94	0.40 ± 0.29
1600, R	0.78 ± 0.24	1.56 ± 0.82	0.53 ± 0.54
1700, L	0.40 ± 0.13	2.47 ± 1.19	<0.09
1800, R	0.67 ± 0.19	1.10 ± 1.02	0.47 ± 0.24
1900, L	0.64 ± 0.21	0.82 ± 0.69	0.37 ± 0.17
2000, R	0.84 ± 0.34	<0.66	0.45 ± 0.27
2100, R	0.85 ± 0.26	2.55 ± 1.53	<0.30
2200, L	0.60 ± 0.21	1.06 ± 0.88	0.61 ± 0.23
2300, R	0.89 ± 0.24	<0.88	1.23 ± 0.52
2400, L	0.46 ± 0.15	<0.52	0.50 ± 0.24
2500, R	0.73 ± 0.16	2.26 ± 0.57	0.47 ± 0.22
2600, L	0.67 ± 0.18	<0.57	0.33 ± 0.30
2700, R	0.91 ± 0.26	1.29 ± 1.20	0.80 ± 0.31
2800, L	0.50 ± 0.16	1.19 ± 0.79	0.37 ± 0.25
2800, L	0.53 ± 0.16	1.03 ± 0.58	0.19 ± 0.15
2900, R	0.79 ± 0.27	<0.59	0.80 ± 0.32
3000, L	0.82 ± 0.26	2.46 ± 1.68	1.06 ± 0.36
3100, R	<0.18	<0.69	0.44 ± 0.38
3200, L	0.53 ± 0.16	1.25 ± 0.56	0.73 ± 0.13
3300, R	0.61 ± 0.17	0.41 ± 0.42	0.60 ± 0.30
3400, L	0.85 ± 0.22	<0.70	0.46 ± 0.23
3500, R	0.73 ± 0.17	1.54 ± 1.22	0.48 ± 0.32
3600, L	0.99 ± 0.23	1.50 ± 0.67	0.64 ± 0.40
3700, R	0.93 ± 0.24	<0.86	0.71 ± 0.27
3800, L	0.88 ± 0.37	1.35 ± 1.01	0.78 ± 0.47
3900, R	0.84 ± 0.28	1.10 ± 1.69	0.51 ± 0.48
4000, L	0.91 ± 0.21	1.65 ± 0.53	1.25 ± 0.36

TABLE 13 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #1
WELDON SPRING, MISSOURI

Location	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
4100, R	0.70 ± 0.16	0.52 ± 1.41	0.51 ± 0.25
4200, L	0.70 ± 0.19	1.01 ± 1.10	0.52 ± 0.30
4300, R	0.91 ± 0.20	1.25 ± 1.28	0.42 ± 0.58
4400, L	0.76 ± 0.22	1.05 ± 0.93	1.11 ± 0.40
4500, R	0.76 ± 0.18	1.67 ± 1.26	0.45 ± 0.23
4600, L	0.59 ± 0.21	0.91 ± 1.25	<0.15
4700, R	0.73 ± 0.21	<0.70	0.58 ± 0.40
4800, L	0.75 ± 0.16	1.05 ± 0.82	0.36 ± 0.22
4900, R	0.56 ± 0.24	<0.66	0.32 ± 0.45
5000, L	0.64 ± 0.22	<0.64	0.45 ± 0.25
5100, R	0.46 ± 0.16	0.50 ± 0.85	0.36 ± 0.21
5200, L	0.63 ± 0.19	<0.70	<0.14
5300, R	0.72 ± 0.18	0.95 ± 1.16	<0.11
5400, L	0.67 ± 0.16	0.65 ± 0.77	0.27 ± 0.18
5500, R	0.93 ± 0.28	<0.73	0.66 ± 0.33
5600, L	0.61 ± 0.15	1.72 ± 0.55	0.45 ± 0.22
5700, R	0.63 ± 0.18	0.84 ± 0.60	0.42 ± 0.30
5800, L	0.74 ± 0.21	<0.80	<0.16
5900, R	0.88 ± 0.23	<0.72	0.60 ± 0.35
6000, L	0.58 ± 0.21	1.01 ± 1.10	0.41 ± 0.28
6100, R	0.80 ± 0.27	1.82 ± 1.67	0.65 ± 0.37
6200, L	0.93 ± 0.20	<0.79	<0.19
6300, R	0.67 ± 0.18	1.57 ± 0.61	0.40 ± 0.55
6400, L	0.46 ± 0.14	<0.48	<0.09
6500, R	0.47 ± 0.15	<0.54	0.27 ± 0.20
6600, L	0.91 ± 0.21	0.88 ± 0.52	0.06 ± 0.07
6700, R	0.54 ± 0.16	<0.37	<0.10
6800, L	0.66 ± 0.17	<0.45	<0.10
6900, R	0.61 ± 0.15	0.75 ± 0.62	0.25 ± 0.15
7000, L	0.67 ± 0.18	0.99 ± 0.71	0.16 ± 0.15
7100, R	0.72 ± 0.17	0.62 ± 0.64	0.23 ± 0.15
7200, L	0.48 ± 0.15	0.52 ± 0.84	0.31 ± 0.14
7300, R	0.47 ± 0.23	<0.54	0.25 ± 0.22
7400, L	0.67 ± 0.13	0.65 ± 0.49	0.34 ± 0.17
7500, R	0.69 ± 0.18	0.69 ± 1.66	0.16 ± 0.12
7600, L	0.49 ± 0.12	1.17 ± 0.34	<0.09
7700, R	0.43 ± 0.17	0.93 ± 1.08	<0.12
7800, L	0.64 ± 0.20	0.61 ± 1.81	0.59 ± 0.22
7900, R	0.83 ± 0.26	<0.64	0.21 ± 0.24
8000, L	0.99 ± 0.31	<0.72	<0.21
8100, R	0.87 ± 0.23	<0.72	<0.18
8200, L	0.64 ± 0.19	0.47 ± 0.70	0.35 ± 0.25

TABLE 13 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #1
WELDON SPRING, MISSOURI

Location	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
8300, R	0.65 ± 0.17	2.14 ± 0.96	<0.13
8400, L	0.60 ± 0.13	1.02 ± 0.55	0.30 ± 0.19
8500, R	0.77 ± 0.20	<0.68	0.42 ± 0.23
8600, L	0.64 ± 0.15	0.64 ± 0.77	0.18 ± 0.11
8700, R	0.68 ± 0.16	<0.51	0.30 ± 0.17
8800, L	0.66 ± 0.17	0.94 ± 1.00	0.25 ± 0.20
8900, R	0.69 ± 0.20	0.87 ± 0.68	0.56 ± 0.30
9000, L	0.62 ± 0.21	<0.43	0.56 ± 0.24
9100, R	0.78 ± 0.28	<0.70	0.39 ± 0.18
9200, L	0.63 ± 0.17	0.59 ± 0.74	0.44 ± 0.26
9300, R	0.67 ± 0.18	<0.50	<0.12
9400, L	0.44 ± 0.20	<0.39	0.29 ± 0.22
9500, R	0.69 ± 0.15	1.86 ± 0.83	0.45 ± 0.21
9600, L	0.67 ± 0.17	0.70 ± 0.32	0.24 ± 0.23
9700, R	0.76 ± 0.17	1.35 ± 0.66	0.36 ± 0.23
9800, L	1.00 ± 0.18	1.65 ± 0.67	0.37 ± 0.35
9900, R	0.78 ± 0.23	1.29 ± 1.35	0.59 ± 0.27
10000, L	0.55 ± 0.13	<0.48	0.18 ± 0.24
10100, R	0.44 ± 0.21	1.02 ± 1.29	0.24 ± 0.29
10200, L	0.84 ± 0.25	1.20 ± 0.48	0.29 ± 0.22
10300, R	0.60 ± 0.23	0.84 ± 1.72	0.55 ± 0.27
10400, L	0.85 ± 0.23	<0.71	1.12 ± 0.32
10500, R	0.82 ± 0.23	1.48 ± 0.58	0.29 ± 0.21
10600, L	0.77 ± 0.29	1.56 ± 1.92	1.09 ± 0.39
10700, R	0.81 ± 0.29	<0.72	0.20 ± 0.39
10800, L	0.85 ± 0.25	0.76 ± 0.84	0.60 ± 0.29
10900, R	0.83 ± 0.22	<0.71	0.72 ± 0.36
11000, L	0.62 ± 0.15	<0.51	0.31 ± 0.17
11100, R	0.66 ± 0.14	1.23 ± 0.49	0.13 ± 0.08
11200, L	0.59 ± 0.20	1.01 ± 1.33	0.37 ± 0.31
11300, R	1.15 ± 0.23	1.21 ± 1.57	0.55 ± 0.37
11400, L	0.81 ± 0.25	1.39 ± 0.75	0.45 ± 0.33
11500, R	0.60 ± 0.17	0.78 ± 0.90	0.51 ± 0.23
11600, L	0.92 ± 0.21	0.91 ± 1.06	0.33 ± 0.28
11700, R	0.82 ± 0.19	1.84 ± 0.68	0.42 ± 0.20
11800, L	0.68 ± 0.24	<0.51	0.29 ± 0.20
11900, R	0.99 ± 0.26	1.60 ± 0.96	0.83 ± 0.42
12000, L	0.84 ± 0.22	0.64 ± 0.62	0.83 ± 0.44
12100, R	0.54 ± 0.17	0.78 ± 1.07	0.23 ± 0.13
12200, L	0.53 ± 0.25	<0.78	0.43 ± 0.37
12300, R	0.90 ± 0.23	0.74 ± 1.08	0.39 ± 0.24
12400, L	0.56 ± 0.16	1.24 ± 0.94	0.51 ± 0.21

TABLE 13 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #1
WELDON SPRING, MISSOURI

Location	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
12500 R	0.50 ± 0.23	1.25 ± 2.74	<0.16
12600, L	0.86 ± 0.20	1.31 ± 0.75	0.43 ± 0.21
12700, R	0.91 ± 0.30	5.52 ± 2.78	1.19 ± 0.52
12800, L	0.57 ± 0.20	2.21 ± 0.87	0.55 ± 0.26
12900, R	0.73 ± 0.30	1.81 ± 2.06	0.98 ± 0.48
13000, L	0.74 ± 0.17	1.73 ± 1.45	0.87 ± 0.44
13100, R	0.47 ± 0.12	0.95 ± 1.18	0.34 ± 0.24
13200, L	0.92 ± 0.25	1.41 ± 1.04	0.90 ± 0.41
13300, R	0.53 ± 0.22	1.08 ± 1.10	0.34 ± 0.24
13400, L	0.80 ± 0.20	0.84 ± 2.19	0.83 ± 0.31
13500, R	0.71 ± 0.23	1.69 ± 0.86	0.49 ± 0.44
13600, L	1.05 ± 0.27	2.05 ± 1.66	1.17 ± 0.40
13700, R	0.62 ± 0.15	1.64 ± 0.99	0.27 ± 0.26
13800, L	1.16 ± 0.26	3.07 ± 1.65	1.14 ± 0.49
13900, R	0.29 ± 0.05	0.43 ± 0.12	0.14 ± 0.05
14000, L	1.21 ± 0.23	2.06 ± 1.64	1.11 ± 0.56
14100, R	0.97 ± 0.19	3.13 ± 0.51	0.35 ± 0.24
14200, L	0.62 ± 0.27	1.22 ± 1.49	0.44 ± 0.39

[a]Refer to Figure 8.
[b]Errors are 2σ based on counting statistics.

TABLE 14

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #2
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, L	1.07 ± 0.28[b]	2.08 ± 1.88	0.87 ± 0.42
100, R	0.38 ± 0.13	0.26 ± 0.32	0.36 ± 0.20
200, L	0.67 ± 0.27	1.38 ± 1.90	0.56 ± 0.43
300, R	0.76 ± 0.19	<0.73	0.58 ± 0.32
400, L	1.03 ± 0.21	<0.69	0.49 ± 0.28
500, R	0.81 ± 0.26	1.19 ± 1.01	0.72 ± 0.32
600, L	0.91 ± 0.31	1.57 ± 1.38	0.36 ± 0.50
700, R	0.96 ± 0.25	<0.82	0.56 ± 0.35
800, L	0.68 ± 0.19	0.88 ± 0.50	0.55 ± 0.43
900, R	0.84 ± 0.22	1.48 ± 0.92	0.85 ± 0.40
1000, L	0.65 ± 0.23	<0.85	0.46 ± 0.26
1100, R	1.21 ± 0.68	0.62 ± 1.01	0.60 ± 0.23
1200, L	0.57 ± 0.21	1.46 ± 1.78	1.27 ± 0.52
1300, R	0.87 ± 0.20	3.47 ± 2.66	0.75 ± 0.33
1400, L	0.64 ± 0.15	0.75 ± 0.75	<0.09
1500, R	0.76 ± 0.23	<0.55	<0.11
1600, L	0.90 ± 0.25	<0.92	0.33 ± 0.28
1700, R	0.87 ± 0.28	0.60 ± 0.59	1.10 ± 0.39
1800, L	1.02 ± 0.26	1.83 ± 1.07	0.99 ± 0.59
1900, L	0.72 ± 0.20	<1.34	0.55 ± 0.30
2000, L	0.39 ± 0.10	0.51 ± 0.28	0.21 ± 0.15
2100, R	0.58 ± 0.19	5.81 ± 1.34	0.39 ± 0.27
2200, L	0.76 ± 0.22	<0.54	<0.14
2300, R	0.65 ± 0.26	2.50 ± 1.58	0.56 ± 0.34
2400, L	0.85 ± 0.29	1.38 ± 1.01	1.04 ± 0.41
2500, R	0.61 ± 0.30	<0.62	0.78 ± 0.38
2600, L	1.10 ± 0.34	1.34 ± 1.91	1.26 ± 0.63
2700, R	1.18 ± 0.26	1.12 ± 0.61	1.30 ± 0.44
2800, L	0.87 ± 0.31	0.97 ± 2.03	1.19 ± 0.69
2900, R	1.16 ± 0.24	4.13 ± 2.21	1.05 ± 0.53
3000, L	0.72 ± 0.23	1.31 ± 0.87	1.08 ± 0.46
3100, R	1.26 ± 0.42	1.66 ± 1.12	1.40 ± 0.65
3200, L	1.13 ± 0.29	1.00 ± 2.59	1.06 ± 0.33

[a]Refer to Figure 8.
[b]Errors are 2σ based on counting statistics.

TABLE 15

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #3
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, L	0.66 ± 0.17[b]	1.25 ± 0.48	0.12 ± 0.11
100, R	0.82 ± 0.25	2.01 ± 1.20	0.25 ± 0.47
200, L	0.83 ± 0.20	1.35 ± 1.30	0.34 ± 0.50
300, R	0.80 ± 0.25	1.50 ± 0.91	0.71 ± 0.51
400, L	1.23 ± 0.48	<1.09	1.01 ± 0.45
500, R	0.72 ± 0.20	0.89 ± 1.01	0.18 ± 0.21
600, L	0.81 ± 0.22	0.87 ± 1.27	0.22 ± 0.23
700, R	0.55 ± 0.15	0.67 ± 1.02	<0.09
800, L	0.69 ± 0.25	<0.57	0.43 ± 0.43
900, R	0.47 ± 0.17	2.13 ± 1.15	0.29 ± 0.25
1000, L	0.68 ± 0.20	<0.59	<0.16
1100, R	0.51 ± 0.16	<0.49	0.32 ± 0.25
1200, L	0.43 ± 0.13	<0.42	<0.11
1300, R	0.70 ± 0.21	1.15 ± 1.14	0.50 ± 0.29
1400, L	0.78 ± 0.28	<0.79	0.74 ± 0.37
1500, R	0.74 ± 0.21	2.85 ± 1.59	0.33 ± 0.19
1600, L	0.61 ± 0.18	1.96 ± 1.01	0.44 ± 0.37
1700, R	0.98 ± 0.22	<0.61	0.66 ± 0.34
1800, L	1.03 ± 0.29	<0.76	1.10 ± 0.37
1900, R	0.73 ± 0.18	<0.60	0.59 ± 0.28
2000, L	1.00 ± 0.33	1.11 ± 1.64	1.28 ± 0.39
2100, L	0.72 ± 0.23	0.98 ± 1.30	0.67 ± 0.42
2200, L	0.98 ± 0.29	1.28 ± 1.51	0.56 ± 0.53
2300, R	1.12 ± 0.24	<0.69	0.32 ± 0.18
2400, L	0.97 ± 0.25	<0.67	0.63 ± 0.26
2500, R	0.76 ± 0.24	0.94 ± 1.51	0.72 ± 0.29
2600, L	0.80 ± 0.22	<0.52	0.24 ± 0.18
2700, R	1.02 ± 0.22	1.87 ± 1.50	0.67 ± 0.39
2800, L	1.19 ± 0.21	1.96 ± 1.49	1.45 ± 0:57
2900, R	1.05 ± 0.21	<0.69	1.16 ± 0.53
3000, L	0.54 ± 0.19	1.41 ± 0.80	1.41 ± 0.80
3100, R	0.61 ± 0.24	<0.70	0.36 ± 0.29
3200, L	0.76 ± 0.24	<0.55	0.48 ± 0.27
3300, R	0.78 ± 0.24	0.59 ± 1.45	0.37 ± 0.32
3400, L	0.74 ± 0.29	<0.62	0.40 ± 0.23
3500, L	1.11 ± 0.32	1.24 ± 1.55	0.79 ± 0.57
3600, R	0.98 ± 0.27	0.93 ± 1.42	1.06 ± 0.45
3700, L	0.86 ± 0.19	<0.63	0.38 ± 0.33

[a]Refer to Figure 9.
[b]Errors are 2σ based on counting statistics.

TABLE 16

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #4
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, L	1.01 ± 0.23[b]	1.24 ± 1.42	0.77 ± 0.42
100, 0.5L	0.73 ± 0.16	<0.50	<0.13
200, 0.5R	0.93 ± 0.22	1.97 ± 1.45	0.80 ± 0.38
300, 0.5L	0.64 ± 0.28	<0.65	0.37 ± 0.33
400, 0.5R	0.64 ± 0.15	<0.49	0.30 ± 0.25
500, 0.5L	0.74 ± 0.21	0.75 ± 1.27	0.29 ± 0.31
600, R	0.90 ± 0.21	<0.50	0.32 ± 0.19
700, L	0.80 ± 0.21	0.89 ± 1.13	<0.13
717, R	0.98 ± 0.21	1.22 ± 0.56	0.69 ± 0.37

[a]Refer to Figure 9.
[b]Errors are 2σ based on counting statistics.

TABLE 17

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #5
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, 0.5R	0.54 ± 0.14[b]	1.45 ± 1.20	<0.17
100, 0.5L	0.39 ± 0.13	<0.63	0.39 ± 0.21
200, 0.5R	0.80 ± 0.29	1.29 ± 1.57	0.41 ± 0.25
300, 0.5L	0.76 ± 0.19	1.16 ± 1.04	0.38 ± 0.38
400, R	0.73 ± 0.17	<0.66	0.34 ± 0.28
500, L	0.54 ± 0.13	0.54 ± 0.67	0.54 ± 0.39
600, R	0.57 ± 0.17	<0.59	0.34 ± 0.33
700, L	0.61 ± 0.17	<0.61	0.44 ± 0.17
800, R	0.62 ± 0.18	<0.55	0.37 ± 0.25
900, L	0.67 ± 0.21	0.63 ± 0.96	0.32 ± 0.24
1100, L	0.67 ± 0.31	<0.84	0.48 ± 0.42
1200, R	0.61 ± 0.15	0.30 ± 0.28	<0.10
1300, L	0.85 ± 0.33	1.54 ± 2.06	0.62 ± 0.34
1400, R	0.88 ± 0.23	1.12 ± 1.16	0.26 ± 0.26
1500, R	0.74 ± 0.15	0.74 ± 0.76	1.12 ± 0.35
1600, L	0.85 ± 0.20	1.15 ± 1.35	0.24 ± 0.32
1700, R	0.65 ± 0.16	<0.56	<0.11
1800, L	0.71 ± 0.16	0.63 ± 0.51	0.33 ± 0.20
1900, R	0.61 ± 0.19	0.70 ± 1.55	<0.13

[a]Refer to Figure 8.
[b]Errors are 2σ based on counting statistics.

TABLE 18

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #6
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, R	0.40 ± 0.16[b]	1.08 ± 0.42	0.79 ± 0.26
100, L	0.69 ± 0.21	1.56 ± 1.60	0.99 ± 0.44
200, R	0.85 ± 0.24	0.64 ± 2.80	1.36 ± 0.42
300, L	0.93 ± 0.18	0.89 ± 0.60	1.15 ± 0.37
400, R	0.44 ± 0.12	0.53 ± 0.67	0.42 ± 0.27
500, L	0.56 ± 0.18	<0.54	0.45 ± 0.20
600, R	0.74 ± 0.27	1.06 ± 1.25	1.35 ± 0.41
700, L	0.36 ± 0.16	0.73 ± 0.39	0.52 ± 0.20
800, R	0.73 ± 0.19	1.02 ± 1.03	0.31 ± 0.23
900, L	0.74 ± 0.18	1.50 ± 1.94	<0.12
1000, R	0.57 ± 0.22	1.16 ± 1.60	0.63 ± 0.24
1100, R	0.63 ± 0.16	2.16 ± 0.52	0.27 ± 0.24
1200, R	1.16 ± 0.28	3.05 ± 1.83	1.54 ± 0.47
1300, L	0.47 ± 0.14	1.44 ± 0.96	0.21 ± 0.25
1400, R	1.07 ± 0.27	<0.87	0.47 ± 0.29
1500, L	0.72 ± 0.24	1.66 ± 0.90	1.27 ± 0.36
1600, R	0.86 ± 0.25	1.23 ± 1.32	0.32 ± 0.27
1700, L	0.84 ± 0.30	2.20 ± 1.87	1.09 ± 0.58
1800, R	0.77 ± 0.16	<0.55	0.41 ± 0.29
1900, L	0.82 ± 0.20	0.84 ± 1.18	0.29 ± 0.51
2000, R	0.77 ± 0.18	<0.74	0.54 ± 0.24
2100, L	1.06 ± 0.21	1.32 ± 1.03	0.97 ± 0.34
2200, R	0.59 ± 0.23	1.62 ± 3.07	<0.18
2300, L	0.48 ± 0.16	1.15 ± 1.59	0.17 ± 0.10
2400, R	0.63 ± 0.15	0.31 ± 0.31	0.18 ± 0.20
2500, L	0.69 ± 0.22	<0.80	0.59 ± 0.26
2600, R	0.87 ± 0.20	<0.67	0.46 ± 0.38

[a]Refer to Figure 9.
[b]Errors are 2σ based on counting statistics.

TABLE 19

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED AT 100 M INTERVALS ALONG ROAD #7
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
0, R	1.00 ± 0.26[b]	1.67 ± 0.69	0.55 ± 0.29
100, L	1.06 ± 0.28	2.56 ± 2.13	0.62 ± 0.44
200, R	0.76 ± 0.16	<0.54	0.53 ± 0.23
300, L	0.75 ± 0.17	0.24 ± 0.40	0.61 ± 0.28
400, R	0.95 ± 0.24	<0.85	0.85 ± 0.35
500, L	0.84 ± 0.24	0.95 ± 0.41	1.92 ± 0.97
600, R	0.79 ± 0.32	1.35 ± 3.73	0.95 ± 0.72
700, L	0.67 ± 0.25	0.48 ± 1.77	0.57 ± 0.36

[a]Refer to Figure 10.
[b]Errors are 2σ based on counting statistics.

TABLE 20

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
DITCH #4
WELDON SPRING, MISSOURI

Location[a] (m)	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
Ditch #4		
0	8	14
100	10	10
200	10	8
300	10	10
400	7	7
500	7	7
600	7	7
700	7	7
800	7	7
900	6	7
1000	6	6
1100	6	6
1200	6	6
1300	6	7
1400	6	6
1500	6	6
Ditch #4A		
0	6	6
100	7	7
200	6	6
300	7	7
400	6	7
500	6	6
600	7	7
700	6	7
800	7	7
877	6	6
Ditch Originating at Loc. #1 0	8	8
100	7	8
200	7	7
300	6	6
400	6	6
500	7	6
600	7	7

[a]Refer to Figure 4.

TABLE 21

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT
COLLECTED AT 100 M INTERVALS - DITCH #4, #4A AND THE DITCH FROM LOCATION #1
WELDON SPRING, MISSOURI

Location[a] (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-238	Th-232
Ditch #4			
0, C	1.02 ± 0.32[b]	59.2 ± 3.6	1.71 ± 0.45
100, C	1.22 ± 0.25	0.52 ± 5.67	1.05 ± 0.55
200, C			
300, C	1.39 ± 0.23	12.1 ± 3.6	1.80 ± 0.72
400, C	1.07 ± 0.22	1.91 ± 2.24	1.33 ± 0.66
500, C			
600, C	1.06 ± 0.26	<1.42	1.13 ± 0.60
700, C	1.57 ± 0.24	2.24 ± 1.24	0.90 ± 0.28
800, C	1.23 ± 0.27	2.43 ± 1.89	1.16 ± 0.49
900, R	0.92 ± 0.23	7.24 ± 3.11	0.86 ± 0.54
1000, L			
1100, R	0.70 ± 0.20	<0.73	0.62 ± 0.34
1200, C	0.91 ± 0.30	0.75 ± 2.58	0.90 ± 0.48
1300, C			
1400, C	0.79 ± 0.21	2.84 ± 1.61	1.10 ± 0.52
1500, R	0.93 ± 0.31	<1.03	2.23 ± 0.61
Ditch #4A			
0, R	1.07 ± 0.22	2.08 ± 1.43	1.15 ± 0.39
100, L	0.86 ± 0.29	1.20 ± 0.56	1.13 ± 0.31
200, R	0.53 ± 0.26	<0.88	1.42 ± 0.37
300, L	0.72 ± 0.25	<1.11	1.18 ± 0.38
400, R	1.36 ± 0.31	2.75 ± 2.02	1.66 ± 1.04
500, L	0.75 ± 0.28	1.41 ± 1.29	1.28 ± 0.41
600, R	0.84 ± 0.22	0.46 ± 0.57	1.53 ± 0.44
700, L	1.03 ± 0.33	3.95 ± 2.41	1.44 ± 0.53
800, R	1.06 ± 0.32	<1.07	0.83 ± 0.39
877, L	0.71 ± 0.20	0.95 ± 0.85	1.22 ± 0.37
Location #1			
0M, C	0.90 ± 0.25[b]	2.19 ± 0.68	1.57 ± 0.38
100M, C	0.90 ± 0.21	7.65 ± 2.07	1.22 ± 0.43
200M, C	0.93 ± 0.34	7.56 ± 2.39	1.52 ± 0.46
300M, C	0.84 ± 0.27	2.77 ± 2.18	1.60 ± 0.50
400M, C	0.63 ± 0.15	1.66 ± 1.00	0.84 ± 0.26
500M, C	0.80 ± 0.20	2.69 ± 0.94	0.97 ± 0.30
600M, C	0.89 ± 0.21	6.58 ± 2.64	1.32 ± 0.61

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.

TABLE 22

RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER SAMPLES
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
Pond Off Railroad #2 (North Bank)	1.93 ± 0.47[b]	8.09 ± 0.78
Pond Off Road #6 (West Bank)	0.74 ± 0.57	2.09 ± 1.00
Raffinate Ditch, 22M	4.28 ± 2.24	3.22 ± 2.57
Ditch 4A - Origin	1.38 ± 0.74	4.98 ± 1.00

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.

TABLE 23

DIRECT RADIATION LEVELS MEASURED AT SOIL SAMPLE LOCATIONS
SCHOTE CREEK
WELDON SPRING, MISSOURI

Location[a] (m)		Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)
0	1R	7	8
100	1L	8	8
200	1R	8	8
300	1L	8	8
400	1R	8	8
500	1L	8	8
600	1R	7	7
700	1L	7	8
727	1R	7	7

[a]Refer to Figure 4.

TABLE 24

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
COLLECTED AT 100 M INTERVALS ALONG SCHOTE CREEK
WELDON SPRING, MISSOURI

Location[a] (m)		Radionuclide Concentrations (pCi/g)		
		Ra-226	U-238	Th-232
0	R	0.93 ± 0.22[b]	1.30 ± 1.74	1.14 ± 0.34
100	L	0.83 ± 0.20	<0.88	1.04 ± 0.34
200,	R	0.60 ± 0.12	1.28 ± 0.70	0.83 ± 0.23
300,	L	0.77 ± 0.24	1.20 ± 1.73	0.99 ± 0.32
400,	R	1.20 ± 0.25	1.54 ± 1.51	1.40 ± 0.46
500,	L	0.58 ± 0.19	0.84 ± 0.64	0.58 ± 0.22
600	L	0.45 ± 0.21	1.16 ± 1.18	0.57 ± 0.46
727,	R	0.44 ± 0.14	0.57 ± 0.59	0.86 ± 0.56

[a] Refer to Figures 4.
[b] Errors are 2σ based on counting statistics.

TABLE 25

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
FROM ARMY PROPERTY PONDS
WELDON SPRING, MISSOURI

Location[a]	Radionuclide Concentrations (pCi/g)		
	Ra-226	U-238	Th-232
Pond Off Railroad #2 (North Bank)	0.54 ± 0.19[b]	0.78 ± 1.21	0.36 ± 0.40
Pond Off Road #6 (West Bank)	1.02 ± 0.27	10.3 ± 2.2	1.43 ± 0.47

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.

TABLE 26

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole[a] Location	Depth (cm)	Radionuclide Concentration (pCi/g) Ra-226	U-238	Th-232
63	0 - 60	1.33 ± 0.46[b]	1.73 ± 1.29	1.15 ± 0.71
	90 - 120	1.11 ± 0.28	<0.85	1.22 ± 0.48
	120 - 150	1.53 ± 0.36	3.15 ± 1.70	1.95 ± 0.60
	240 - 270	0.67 ± 0.24	<0.84	1.49 ± 0.42
	270 - 300	0.83 ± 0.32	2.34 ± 1.88	1.68 ± 0.91
	390 - 420	0.85 ± 0.30	<0.87	1.50 ± 0.47
	420 - 450	0.88 ± 0.29	3.34 ± 1.11	2.02 ± 0.51
	540 - 550	0.85 ± 0.30	<0.92	0.61 ± 0.57
64	0 - 30	1.24 ± 0.49	<1.32	1.63 ± 0.87
	30 - 60	0.97 ± 0.29	1.69 + 2.09	1.65 ± 0.45
	90 - 120	1.16 ± 0.38	2.79 + 1.36	1.95 ± 0.70
	120 - 150	1.32 ± 0.33	1.46 + 1.54	1.12 ± 0.78
	240 - 270	0.96 ± 0.31	1.81 + 1.72	1.44 ± 0.73
	270 - 300	1.04 ± 0.29	1.68 ± 1.54	1.37 ± 0.52
	390 - 420	0.88 ± 0.35	1.28 ± 0.82	1.29 ± 0.49
	420 - 450	1.07 ± 0.42	<1.12	1.89 ± 0.62
65	0 - 30	1.06 ± 0.34	1.71 ± 1.50	1.17 ± 0.57
	30 - 60	1.17 ± 0.30	8.87 ± 2.80	2.13 ± 0.61
	90 - 120	1.18 ± 0.29	3.45 ± 1.28	1.48 ± 0.52
	120 - 150	1.25 ± 0.30	1.18 ± 1.52	1.60 ± 0.48
	240 - 270	0.90 ± 0.26	1.16 ± 0.78	1.35 ± 0.55
	270 - 300	0.63 ± 0.30	1.62 ± 1.64	1.25 ± 0.65
66	0 - 30	1.21 ± 0.35	2.18 ± 1.73	1.42 ± 0.57
	30 - 60	1.19 ± 0.35	1.93 ± 1.46	1.96 ± 0.56
	90 - 120	1.66 ± 0.36	<1.22	1.06 ± 0.75
	120 - 150	1.86 ± 0.35	6.79 ± 1.60	1.57 ± 0.71
	240 - 270	0.98 ± 0.28	1.44 ± 1.68	2.01 ± 0.55
	270 - 300	0.71 ± 0.28	1.98 ± 1.67	1.16 ± 0.51
	390 - 405	1.24 ± 0.57	3.34 ± 1.65	2.30 ± 0.74
	540 - 555	1.46 ± 0.99	3.41 ± 6.78	2.69 ± 2.21
67	0 - 30	0.99 ± 0.32	3.32 ± 2.78	<0.21
	30 - 60	1.02 ± 0.37	4.85 ± 1.70	1.45 ± 0.92
	90 - 120	1.08 ± 0.34	<0.87	1.01 ± 0.56
	120 - 150	0.59 ± 0.35	1.60 ± 2.06	1.20 ± 0.72
	240 - 270	0.75 ± 0.25	<0.81	1.19 ± 0.39
	270 - 300	1.13 ± 0.33	<0.88	1.24 ± 0.61
	390 - 420	0.32 ± 0.25	<0.88	1.09 ± 0.48
	420 - 450	0.54 ± 0.29	0.86 ± 1.76	1.11 ± 0.41

TABLE 26 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole Location	Depth (cm)	Radionuclide Concentration (pCi/g) Ra-226	U-238	Th-232
68	0 - 30	1.24 ± 0.29	3.93 ± 2.66	1.66 ± 0.89
	30 - 60	1.00 ± 0.43	6.00 ± 2.67	1.41 ± 0.67
	90 - 120	0.85 ± 0.27	1.16 ± 2.13	1.15 ± 0.49
	120 - 150	0.83 ± 0.32	<0.79	1.45 ± 0.71
	240 - 255	0.32 ± 0.28	<0.63	0.55 ± 0.30
	390 - 450	0.25 ± 0.21	1.90 ± 1.29	0.30 ± 0.43
	540 - 570	0.37 ± 0.23	<0.71	0.32 ± 0.32
69	0 - 30	0.97 ± 0.33	2.03 ± 1.02	0.80 ± 0.36
	30 - 60	0.58 ± 0.27	0.71 ± 1.35	0.98 ± 0.39
	90 - 120	0.79 ± 0.26	1.93 ± 1.09	1.18 ± 0.41
	120 - 150	0.74 ± 0.26	0.62 ± 0.93	1.39 ± 0.47
	240 - 270	1.01 ± 0.30	1.52 ± 0.95	1.74 ± 0.52
	270 - 300	1.11 ± 0.34	1.34 ± 1.33	1.54 ± 0.48
	390 - 420	0.82 ± 0.28	1.42 ± 1.19	1.08 ± 0.41
	420 - 450	0.67 ± 0.36	<0.65	1.09 ± 0.44
	540 - 545	1.52 ± 0.85	2.82 ± 1.98	<0.72
70	0 - 30	1.00 ± 0.27	<0.91	1.11 ± 0.42
	30 - 60	1.24 ± 0.40	3.49 ± 1.09	1.62 ± 0.87
	90 - 120	1.42 ± 0.38	2.00 ± 1.67	1.47 ± 0.63
	120 - 150	1.20 ± 0.36	2.53 ± 1.48	1.77 ± 0.58
	240 - 270	1.20 ± 0.29	2.01 ± 1.32	1.31 ± 0.70
	270 - 300	0.83 ± 0.27	1.37 ± 1.76	1.38 ± 0.78
	390 - 420	0.68 ± 0.29	<0.73	0.88 ± 0.49
	420 - 450	0.64 ± 0.32	0.34 ± 0.78	
71	0 - 30	0.94 ± 0.31	<0.86	1.03 ± 0.58
	30 - 60	1.01 ± 0.35	1.06 ± 0.75	0.25 ± 0.37
	90 - 120	1.11 ± 0.35	1.18 ± 1.83	1.22 ± 0.56
	120 - 150	1.55 ± 0.33	2.53 ± 1.04	1.34 ± 0.64
	240 - 270	0.74 ± 0.29	<0.79	0.86 ± 0.34
	390 - 420	0.64 ± 0.23	1.84 ± 0.77	1.56 ± 0.48
	420 - 450	0.81 ± 0.24	0.89 ± 1.64	1.02 ± 0.38
	540 - 570	0.49 ± 0.34	<0.86	1.58 ± 0.43
	570 - 600	0.62 ± 0.27	1.21 ± 1.62	0.68 ± 0.60
	690 - 720	1.32 ± 0.33	2.29 ± 1.50	2.11 ± 0.69
	720 - 750	2.11 ± 0.38	9.88 ± 2.66	2.58 ± 0.67
	840 - 870	1.35 ± 0.40	2.49 ± 1.46	2.71 ± 0.57
	870 - 900	1.18 ± 0.29	<0.98	2.10 ± 0.74
	990 - 102	1.28 ± 0.30	2.09 ± 1.36	1.79 ± 0.47
	1140 - 1155	0.58 ± 0.28	0.92 ± 1.40	1.39 ± 0.47

TABLE 26 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole Location	Depth (cm)	Radionuclide Concentration (pCi/g) Ra-226	U-238	Th-232
72	0 - 30	0.88 ± 0.27	0.66 ± 0.66	0.76 ± 0.41
	30 - 60	1.27 ± 0.26	1.91 ± 1.34	1.29 ± 0.37
	90 - 120	1.16 ± 0.37	2.77 ± 1.67	1.60 ± 0.78
	120 - 150	1.04 ± 0.27	1.84 ± 1.66	1.52 ± 0.57
	240 - 270	1.03 ± 0.34	1.02 ± 1.57	1.41 ± 0.48
	270 - 300	0.89 ± 0.23	1.14 ± 1.63	1.41 ± 0.67
	390 - 420	0.82 ± 0.36	1.87 ± 0.85	1.26 ± 0.49
	420 - 450	0.66 ± 0.20	<0.70	1.17 ± 0.46
	540 - 550	0.63 ± 0.56	3.51 ± 1.41	1.25 ± 0.63
73	0 - 30	0.63 ± 0.43	<0.78	0.97 ± 0.54
	30 - 60	0.44 ± 0.17	1.71 ± 0.80	0.51 ± 0.26
	90 - 120	0.71 ± 0.23	3.09 ± 1.76	0.83 ± 0.39
	120 - 150	0.42 ± 0.17	<0.79	<0.25
	240 - 270	0.61 ± 0.20	3.28 ± 1.46	0.67 ± 0.63
	270 - 300	0.40 ± 0.33	1.53 ± 1.37	1.21 ± 0.49
	390 - 450	0.38 ± 0.22	<0.68	0.81 ± 0.30
	540 - 570	0.56 ± 0.21	1.70 ± 0.89	1.45 ± 0.59
	570 - 600	0.59 ± 0.30	<0.78	1.05 ± 0.44
	690 - 720	0.69 ± 0.21	1.33 ± 1.26	0.86 ± 0.55
	720 - 750	0.63 ± 0.35	<0.72	1.05 ± 0.53
	840 - 870	0.53 ± 0.27	0.30 ± 0.59	0.89 ± 0.41
	870 - 900	0.64 ± 0.33	<0.83	1.44 ± 0.47
	990 - 1020	1.50 ± 0.29	2.16 ± 0.80	1.07 ± 0.37
74	0 - 30	1.37 ± 0.53	3.05 ± 1.24	1.63 ± 0.90
	30 - 60	0.91 ± 0.32	1.97 ± 1.47	1.70 ± 0.49
	90 - 120	0.89 ± 0.25	2.06 ± 1.19	1.28 ± 0.36
	120 - 150	0.83 ± 0.28	0.55 ± 2.13	1.24 ± 0.41
	240 - 270	0.93 ± 0.23	0.93 ± 1.24	1.40 ± 0.46
	270 - 300	0.79 ± 0.26	<0.80	1.66 ± 0.41
	390 - 420	0.78 ± 0.30	0.65 ± 0.73	1.33 ± 0.77
	420 - 450	0.69 ± 0.20	1.27 ± 1.40	0.88 ± 0.46
	540 - 570	0.71 ± 0.34	1.50 ± 1.32	0.93 ± 0.40
	570 - 600	0.75 ± 0.21	4.09 ± 1.23	1.59 ± 0.53
	690 - 720	0.75 ± 0.35	<0.89	1.15 ± 0.48
	720 - 750	0.97 ± 0.38	<1.23	1.49 ± 0.73
	840 - 870	0.76 ± 0.27	1.87 ± 1.24	1.07 ± 0.56
	870 - 900	0.85 ± 0.21	1.87 ± 1.19	0.93 ± 0.49
	990 - 1020	0.90 ± 0.30	1.24 ± 1.86	1.51 ± 0.51
	1020 - 1050	0.58 ± 0.26	<0.76	1.54 ± 0.54
	1140 - 1170	0.61 ± 0.22	1.37 ± 1.27	1.56 ± 0.54

TABLE 26 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole Location	Depth (cm)	Radionuclide Concentration (pCi/g) Ra-226	U-238	Th-232
	1170 - 1200	0.63 ± 0.22	0.94 ± 1.36	1.42 ± 0.41
	1290 - 1320	0.74 ± 0.30	1.42 ± 1.43	0.83 ± 0.43
	1320 - 1350	0.82 ± 0.25	3.37 ± 1.55	1.04 ± 0.65
	1440 - 1470	2.18 ± 0.39	2.10 ± 1.39	1.07 ± 0.66
	1470 - 1500	1.91 ± 0.37	6.41 ± 2.49	1.36 ± 0.55
	1590 - 1620	1.19 ± 0.27	1.51 ± 1.10	1.44 ± 0.47
	1620 - 2650	1.02 ± 0.34	<0.91	1.79 ± 0.43
75	0 - 30	<0.50	1.43 ± 1.06	1.74 ± 0.76
	30 - 60	1.15 ± 0.33	1.16 ± 2.19	2.38 ± 0.66
	90 - 120	1.55 ± 0.43	2.33 ± 2.17	1.56 ± 0.58
	120 - 150	1.04 ± 0.37	<1.14	1.31 ± 0.68
	240 - 270	0.82 ± 0.22	0.56 ± 0.65	1.37 ± 0.58
	270 - 300	0.99 ± 0.32	<0.97	1.76 ± 0.64
	390 - 420	0.93 ± 0.24	1.44 ± 0.79	1.43 ± 0.61
	420 - 450	0.79 ± 0.31	<0.87	0.75 ± 0.55
	540 - 570	0.59 ± 0.36	1.40 ± 1.28	1.39 ± 0.64
	570 - 600	0.83 ± 0.41	1.11 ± 0.86	1.09 ± 0.44
	690 - 720	0.52 ± 0.36	<0.99	1.45 ± 0.52
76	0 - 30	0.96 ± 0.31	<0.83	1.59 ± 0.58
	30 - 60	1.01 ± 0.30	1.40 ± 1.66	0.51 ± 0.96
	120 - 150	0.85 ± 0.28	1.12 ± 1.51	1.56 ± 0.50
	120 - 150	0.94 ± 0.32	2.30 ± 0.96	1.46 ± 0.59
	240 - 270	0.94 ± 0.28	0.90 ± 1.81	1.37 ± 0.56
	270 - 300	0.78 ± 0.28	1.89 ± 1.47	1.00 ± 0.36
	390 - 420	0.63 ± 0.21	<0.64	0.61 ± 0.38
	420 - 450	0.60 ± 0.29	1.38 ± 1.09	1.29 ± 0.41
	540 - 570	0.89 ± 0.40	<1.22	1.68 ± 0.67
	570 - 600	0.92 ± 0.40	1.82 ± 0.93	1.42 ± 0.92
	690 - 720	0.48 ± 0.27	<0.66	0.78 ± 0.41
	720 - 750	0.33 ± 0.19	0.93 ± 0.97	0.54 ± 0.35
	840 - 870	0.65 ± .22	<0.64	1.05 ± 0.39
	870 - 900	0.91 ± 0.35	1.38 ± 0.87	0.96 ± 0.71
	990 - 1020	0.82 ± 0.31	1.78 ± 1.20	1.37 ± 0.57
	1020 - 1050	1.33 ± 0.30	3.02 ± 1.45	1.41 ± 0.55
	1140 - 1170	0.75 ± 0.38	<1.12	1.12 ± 0.43
	1170 - 1200	1.25 ± 0.32	<0.93	1.10 ± 0.57
77	0 - 30	0.58 ± 0.27	0.97 ± 1.95	0.63 ± 0.38
	30 - 60	0.82 ± 0.27	<0.62	0.35 ± 0.28
	90 - 120	1.31 ± 0.35	2.73 ± 1.01	1.61 ± 0.60

TABLE 26 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole Location	Depth (cm)	Radionuclide Concentration (pCi/g) Ra-226	U-238	Th-232
77	120 - 150	0.80 ± 0.25	1.04 ± 1.80	1.35 ± 0.54
	240 - 270	0.70 ± 0.30	1.60 ± 1.07	0.82 ± 0.50
	270 - 300	0.93 ± 0.36	2.01 ± 1.95	1.42 ± 0.46
	390 - 420	0.82 ± 0.20	2.77 ± 1.02	1.40 ± 0.41
	420 - 450	0.70 ± 0.50	1.79 ± 1.41	0.97 ± 0.51
	540 - 570	1.55 ± 0.28	1.40 ± 1.38	1.64 ± 0.40
	570 - 600	1.04 ± 0.37	1.76 ± 1.92	1.83 ± 0.57
	690 - 720	0.94 ± 0.22	1.62 ± 1.52	0.97 ± 0.43
	720 - 750	1.07 ± 0.38	1.23 ± 1.42	1.15 ± 0.79
78	0 - 30	0.86 ± 0.30	1.16 ± 2.23	0.50 ± 0.25
	30 - 60	0.61 ± 0.20	1.11 ± 0.93	<0.24
	90 - 120	0.94 ± 0.28	1.22 ± 1.10	0.88 ± 0.35
	120 - 150	1.12 ± 0.26	1.34 ± 1.31	0.56 ± 0.54
	240 - 270	1.15 ± 0.22	1.10 ± 1.08	1.05 ± 0.36
	270 - 300	1.32 ± 0.33	1.57 ± 0.84	1.36 ± 0.59
	390 - 420	0.80 ± 0.25	<0.78	0.89 ± 0.33
	420 - 450	0.82 ± 0.30	<1.12	0.23 ± 0.28
	540 - 570	0.70 ± 0.38	0.98 ± 2.01	1.11 ± 0.37
	570 - 600	0.76 ± 0.22	1.66 ± 1.42	0.95 ± 0.54
	690 - 705	0.19 ± 0.15	0.85 ± 1.17	<0.16
	840 - 870	0.41 ± 0.31	0.79 ± 1.68	0.77 ± 0.33
	870 - 900	<0.15	<0.77	<0.27
	1020 - 1050	1.17 ± 0.26	1.39 ± 1.34	1.74 ± 0.50
79	0 - 30	1.33 ± 0.37	2.34 ± 2.18	1.19 ± 0.55
	30 - 60	<0.24	<1.04	1.14 ± 0.51
	90 - 120	0.98 ± 0.41	1.03 ± 2.85	1.57 ± 0.50
	120 - 150	1.19 ± 0.39	0.93 ± 1.00	0.98 ± 0.66
	240 - 270	0.62 ± 0.37	1.66 ± 1.76	0.85 ± 0.38
	270 - 300	0.69 ± 0.29	2.32 ± 0.84	1.45 ± 0.53
	390 - 420	1.04 ± 0.44	2.08 ± 1.86	1.17 ± 0.53
80	0 - 30	1.43 ± 0.47	4.12 ± 1.26	1.22 ± 0.86
	30 - 60	0.95 ± 0.26	<0.80	1.45 ± 0.52
	90 - 120	1.09 ± 0.34	<1.08	1.74 ± 0.87
	120 - 150	1.26 ± 0.39	2.31 ± 1.75	1.52 ± 0.80
	240 - 270	<0.15	3.08 ± 1.82	1.07 ± 0.40
	270 - 300	0.74 ± 0.22	1.28 ± 0.75	1.89 ± 0.48
	390 - 420	0.91 ± 0.33	<0.98	2.03 ± 0.51
	420 - 450	0.77 ± 0.38	<1.13	1.22 ± 0.48
	540 - 570	0.67 ± 0.22	1.98 ± 1.21	0.61 ± 0.33

TABLE 26 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SPLIT SPOON SOIL SAMPLES
COLLECTED FROM BOREHOLES ON THE ARMY RESERVE PROPERTY
WELDON SPRING, MISSOURI

Borehole Location	Depth (cm)	Radionuclide Concentration (pCi/g)		
		Ra-226	U-238	Th-232
82	0 - 30	1.09 ± 0.42	1.65 ± 2.36	1.12 ± 0.46
	30 - 60	1.89 ± 0.46	6.11 ± 2.66	0.70 ± 0.85
	90 - 120	1.07 ± 0.33	<2.67	1.32 ± 0.76
	120 - 150	3.07 ± 0.51	<1.22	0.74 ± 0.62
	240 - 270	0.34 ± 0.42	1.64 ± 0.73	0.69 ± 0.52
	270 - 300	0.46 ± 0.24	<0.65	<0.26
	370 - 420	0.30 ± 0.19	0.97 ± 1.06	0.68 ± 0.40
	420 - 450	<0.18	<1.01	0.78 ± 0.62
	540 - 570	0.64 ± 0.32	1.17 ± 1.86	<0.38
	570 - 600	<0.28	<1.07	<0.37

[a]Refer to Figure 3.
[b]Errors are 2σ based on counting statistics.

APPENDIX A

Major Sampling and Analytical Equipment

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline RASCAL
Portable Scaler/Ratemeter
Model PRS-1
(Eberline, Sante Fe, NM)

Eberline PRM-6
Portable Ratemeter
(Eberline, Sante Fe, NM)

Eberline Alpha Scintillation Probe
Model AC-3-7
(Eberline, Sante Fe, NM)

Eberline Beta-Gamma Pancake Probe
Model HP-260
(Eberline, Sante Fe, NM)

Victoreen NaI Gamma Scintillation Probe
Model 489-55
(Victoreen, Cleveland, OH)

Reuter-Stokes Pressurized Ionization Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

Ludlum Portable Scaler
Model 2200
(Ludlum, Sweetwater, TX)

B. Laboratory Analysis

Automatic low-background Alpha-Beta Counter
Model LB5110-2080
(Tennelec, Inc., Oak Ridge, TN)

Ge(Li) Detectors (2)
Model LGCC2220SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, SPG-16
(Applied Physical Technology Smyrna, GA)

High-Purity Germanium Detector
Model GMX-23195-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Gamma Products, Inc., Palos Hills, IL)

ND-66/ND-680 System
(Nuclear Data, Inc., Schaumburg, IL)

Alpha Spectrometry System
Tennelec Electronics, EG&G ORTEC
Surface barrier detectors
(Tennelec, Inc., EG&G, Oak Ridge, TN)

Radon Emanation System
Counter/Timer, Model 2071
Single Channel Analyzer, Model 2031
High Voltage Power Supply, Model 3102
(Canberra Industries, Meriden, CT)

Tennelec Linear Amplifier
Model TC 202BLR
(Tennelec, Inc., Oak Ridge, TN)

Radon Bubblers and Lucas Cells
(Rocky Mountain Scientific Glass Blowing, Co., Aurora, CO)

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX B

Measurement and Analytical Procedures

Gamma Scintillation Measurement

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure rates (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at locations on the Busch Wildlife and Weldon Spring Wildlife areas.

Alpha and Beta-Gamma Measurements

Measurements of total alpha radiation levels were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model AC-3-7 alpha scintillation probes. Measurements of direct beta-gamma radiation levels were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model HP-260 thin-window pancake G-M probes. Count rates (cpm) were converted to disintegration rates (dpm/100 cm^2) by dividing the net rate by the 4π efficiency and correcting for active area of the detector. The effective window area is 59 cm^2 for the ZnS detectors and 15 cm^2 for the G-M detectors. The average background count rate was 40 cpm for the G-M probes and approximately 2 cpm for the ZnS alpha probes.

Beta and gamma dose rates were calculated individually and the results summed for a combined beta-gamma dose rate. Beta dose rates were calculated by applying the conversion factor of 1400 cpm/mrad/h to the net beta count rate.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod

holder with a small winch. Measurements were performed at 30 cm intervals in all holes. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations.

Soil and Sediment Sample Analysis

Gamma Spectrometry

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5 L Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium and Ge(Li) detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
or 1.001 MeV from Pa-234 (secular equilibrium assumed)

Alpha Spectrometry; Th-230

Thorium was separated by a process of high temperature fusion, acid dissolution, precipitation, redissolution, and solvent extraction. The thorium was then precipitated with cerium fluoride onto counting discs. Surface barrier detectors coupled to a Nuclear Data Model ND 680 pulse height analyzer enabled identification of the characteristic Th-230 energy peak (4.68 MeV) and activity determination.

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through

0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. A known volume of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB-5110 low-background proportional counter.

Analysis for Ra-226 and Ra-228 was performed using the standard technique EPA 600/4-80-032.

Uranium and thorium isotopic analyses were performed by taking aliquots of liquid, then acidifying and evaporating to dryness. The residue was dissolved by pyrosulfate fusion and precipitated with barium sulfate. The barium sulfate precipitate was redissolved and the uranium and thorium separated by liquid - liquid extraction. The uranium and thorium were then precipitated with a cerium fluoride carrier and counted using surface barrier detectors (ORTEC), alpha spectrometers (Tennelec), and an ND-66 Multichannel Analyzer (Nuclear Data).

Removable Contamination Measurements

Smear measurements were performed on numbered filter paper disks, 47 mm in diameter. Each smear was sealed in a labeled envelope with the location and other pertinent information recorded. A low-background alpha-beta counting system was used to count individual smears.

Errors and Detection Limits

The uncertainties associated with the analytical data, presented in the tables of this report, represent the 95% (2σ) confidence levels based only on counting statistics. Other sources of error associated with the sampling and analyses introduce an additional uncertainty of ± 6 to 10% in the results.

Calibration and Quality Assurance

Laboratory and field survey procedures are documented in manuals developed specifically for the Oak Ridge Associated Universities Radiological Site Assessment Program.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NBS-traceable standards. The calibration procedures for the portable gamma instruments are performed by comparison with an NBS calibrated pressurized ionization chamber.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and EML Quality Assurance Programs.

APPENDIX C

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO VICINITY PROPERTIES AT THE WELDON SPRING CHEMICAL PLANT SITE

U.S. DEPARTMENT OF ENERGY GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(Rev. 1, July 1985)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive materials and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactivity, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Dept. Energy 1984). More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactivity from basic dose limits, is contained in a supplementary document--referred to herein as the "supplement" (U.S. Dept. Energy 1985).

"Residual radioactivity" includes: (1) residual concentrations of radionuclides in soil material,** (2) concentrations of airborne radon decay products, (3) external gamma radiation level, and (4) surface contamination. A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). Basic dose limits are used explicitly for deriving guidelines for residual concentrations of radionuclides in soil material, except for thorium and radium. Guidelines for

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*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**The term "soil material" refers to all material below grade level after remedial action is completed.

residual concentrations of thorium and radium and for the other three quantities (airborne radon decay products, external gamma radiation level, and surface contamination) are based on existing radiological protection standards (U.S. Environ. Prot. Agency 1983; U.S. Nucl. Reg. Comm. 1982). These standards are assumed to be consistent with basic dose limits within the uncertainty of derivations of levels of residual radioactivity from basic limits.

A "guideline" for residual radioactivity is a level of residual radioactivity that is acceptable if the use of the site is to be unrestricted. Guidelines for residual radioactivity presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards, and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement.

An "authorized limit" is a level of residual radioactivity that must not be exceeded if the remedial action is to be considered completed. Under normal circumstances, expected to occur at most sites, authorized limits for residual radioactivity are set equal to guideline values. Exceptional conditions for which authorized limits might differ from guideline values are specified in Sections D and F. A site may be released for unrestricted use only if the residual radioactivity does not exceed guideline values at the time remedial action is completed. Restrictions and controls on use of the site must be established and enforced if the residual radioactivity exceeds guideline values. The applicable controls and restrictions are specified in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). Implementation of ALARA policy is specified as procedures to be applied after authorized limits have been set. For sites to be released for unrestricted use, the intent is to reduce residual radioactivity to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual radioactivity is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to levels that are as low as is reasonably achievable. Procedures for implementing ALARA policy are described in the supplement. ALARA policies, procedures, and actions must be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 500 mrem/yr for a period of exposure not to exceed 5 years and an average of 100 mrem/yr over a lifetime. The committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), shall be used for determining the dose.

C. GUIDELINES FOR RESIDUAL RADIOACTIVITY

C.1 Residual Radionuclides in Soil Material

Residual concentrations of radionuclides in soil material shall be specified as above-background concentrations averaged over an area of 100 m^2. If the concentration in any area is found to exceed the average by a factor greater than 3, guidelines for local concentrations shall also be applicable. These "hot spot" guidelines depend on the extent of the elevated local concentrations and are given in the supplement.

The generic guidelines for residual concentrations of Th-232, Th-230, Ra-228, and Ra-226 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface
- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that the dose for the mixtures will not exceed the basic dose limit. Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

The guidelines for residual concentrations in soil material of all other radionuclides shall be derived from basic dose limits by means of an environmental pathway analysis using site-specific data. Procedures for deriving these guidelines are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

C.3 External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μR/h.

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*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.4 Surface Contamination

The following generic guidelines, adapted from standards of the U.S. Nuclear Regulatory Commission (1982), are applicable only to existing structures and equipment that will not be demolished and buried. They apply to both interior and exterior surfaces. If a building is demolished and buried, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

Radionuclides†[2]	Allowable Total Residual Surface Contamination (dpm/100 cm^2)†[1]		
	Average†[3],†[4]	Maximum†[4],†[5]	Removable†[4],†[6]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

†[1] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

†[2] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

†[3] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

†[4] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

†[5] The maximum contamination level applies to an area of not more than 100 cm^2.

†[6] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVITY

The remedial action shall not be considered complete unless the residual radioactivity is below authorized limits. Authorized limits shall be set equal to guidelines for residual radioactivity unless: (1) exceptions specified in Section F of this document are applicable, in which case an authorized limit may be set above the guideline value for the specific location or condition to which the exception is applicable; or (2) on the basis of site-specific data not used in establishing the guidelines, it can be clearly established that limits below the guidelines are reasonable and can be achieved without appreciable increase in cost of the remedial action. Authorized limits that differ from guidelines must be justified and established on a site-specific basis, with documentation that must be filed as a permanent record upon completion of remedial action at a site. Authorized limits differing from the guidelines must be approved by the Director, Oak Ridge Technical Services Division, for FUSRAP and by the Director, Richland Surplus Facilities Management Program Office, for remote SFMP--with concurrence by the Director of Remedial Action Projects for both programs.

E. CONTROL OF RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

Residual radioactivity above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A requires compliance with applicable federal, state, and local environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to interim storage, interim management, and long-term management.

a. 5440.1B, Implementation of the National Environmental Policy Act

b. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations

c. 5480.2, Hazardous and Radioactive Mixed Waste Management

d. 5480.4, Environmental Protection, Safety, and Health Protection Standards

e. 5482.1A, Environmental, Safety, and Health Appraisal Program

f. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

g. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

h. 5484.2, Unusual Occurrence Reporting System

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed: (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive materials shall not exceed existing federal, state, or local standards.

d. Access to a site shall be controlled and misuse of onsite material contaminated by residual radioactivity shall be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The federal government shall have title to the property.

E.2 Interim Management

a. A site may be released under interim management when the residual radioactivity exceeds guideline values if the residual radioactivity is in inaccessible locations and would be unreasonably costly to remove, provided that administrative controls are established to ensure that no member of the public shall receive a radiation dose exceeding the basic dose limit.

b. The administrative controls, as approved by DOE, shall include but not be limited to periodic monitoring, appropriate shielding, physical barriers to prevent access, and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactivity or cause it to migrate.

c. The owner of the site or appropriate federal, state, or local authorities shall be responsible for enforcing the administrative controls.

E.3 Long-Term Management

Uranium, Thorium, and Their Decay Products

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the waste shall not: (1) exceed an annual average release rate of 20 $pCi/m^2/s$, and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b of this section (E.3) to be exceeded, and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a of this section (E.3).

d. Groundwater shall be protected in accordance with 40 CFR 192.20(a)(2) and 192.20(a)(3), as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The federal government shall have title to the property.

Other Radionuclides

f. Long-term management of other radionuclides shall be in accordance with Chapters 2, 3, and 5 of DOE Order 5820.2, as applicable.

F. EXCEPTIONS

Exceptions to the requirement that authorized limits be set equal to the guidelines may be made on the basis of an analysis of site-specific aspects of a designated site that were not taken into account in deriving the guidelines. Exceptions require approvals as stated in Section D. Specific situations that warrant exceptions are:

a. Where remedial actions would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial actions--even after all reasonable mitigative measures have been taken--would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive materials do not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial actions will generally not

be necessary where only minor quantities of residual radioactive materials are involved or where residual radioactive materials occur in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples are residual radioactive materials under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. In order to invoke this exception, a site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the residual radioactivity must be included in the appropriate state and local records.

d. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be effected by remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of remedial actions that would be less costly than removal of the residual radioactive materials. A statement specifying the residual radioactivity must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry Model and Dose Limits	International Commission on Radiological Protection (1977, 1978)
Generic Guidelines for Residual Radioactivity	
Residual Concentrations of Radium and Thorium in Soil Material	40 CFR 192
Airborne Radon Decay Products	40 CFR 192
External Gamma Radiation	40 CFR 192
Surface Contamination	Adapted from U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	DOE Order 5480.1A; 40 CFR 192

H. REFERENCES

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URANIUM SITE SPECIFIC SOIL GUIDELINES FOR THE U.S. ARMY RESERVE PROPERTY

developed by

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Uranium site-specific soil guidelines where derived for the U.S. Army Reserve property adjacent to the Weldon Spring Chemical Plant. These derived soil guidelines (Gilbert 1986) are based on the requirement that the average annual committed effective dose equivalent to an individual should not exceed a basic dose limit of 100 mrem/yr above background (U.S. Dept. Energy 1985). Procedures specified in the DOE manual for implementing residual radioactivity guidelines were used to carry out the derivation (Gilbert et al. 1985).

It was calculated that the basic dose limit would not be exceeded if the average concentration of U-238 within contaminated zones does not exceed 60 pCi/g. This guideline value applies to the activity concentration of U-238 when no principal radionuclides other than U-238 and U-234 are present in above-background concentrations and when U-238 and U-234 are both present in secular equilibrium. In those locations, where other radionuclides are present in above-background concentrations, the mixture sum formula (Gilbert et al. 1985---Section 5.4.2) would be used to determine if guidelines are met.

For small, isolated areas on this property, soil concentrations of U-238 in excess of the above guideline levels are allowable, provided it can be established that the basic dose limit is not exceeded.

The foregoing guidelines are based solely on the requirement that the estimated potential dose to an onsite resident should not exceed 100 mrem/yr. An additional DOE requirement is that the radiation dose to individuals and groups should be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account (Gilbert et al. 1985—Section 6).

REFERENCES

Gilbert, T.L. 1986. Derivation of Site-Specific Soil Guidelines for Weldon Spring Vicinity Properties - I. U.S. Army Reserve Property. Prepared by Environmental Research Division, Argonne National Laboratory, for Division of Facility and Site Decommissioning, U.S. Department of Energy. Draft Report, January 1986.

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